

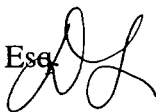


**UNITED STATES ENVIRONMENTAL PROTECTION AGENCY**  
OFFICE OF CRIMINAL ENFORCEMENT, FORENSICS AND TRAINING  
NATIONAL ENFORCEMENT INVESTIGATIONS CENTER  
BUILDING 53, BOX 25227, DENVER FEDERAL CENTER  
DENVER, COLORADO 80225

July 3, 2001

**MEMORANDUM**

**SUBJECT: Source Identification of Lead Contamination  
in the Soil of the Westgate Trailer Park,  
Greer, South Carolina  
Project No. SP0049 (VP0300, R55)**

**FROM: Diana A. Love, Esq.**  
Director, NEIC 

**TO: Beverly Spagg, Chief,  
AEEB, APTMD, EPA Region 4**

Enclosed is the technical report for the subject case. Additional copies of the report have been enclosed for your convenience. If there are any questions, please contact Dr. Steve Machemer at (303) 236-6093.

**Attachment**

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**UNITED STATES ENVIRONMENTAL PROTECTION AGENCY**

**Office of Enforcement and Compliance Assurance  
Office of Criminal Enforcement, Forensics and Training**

**ENFORCEMENT CONFIDENTIAL**

**EPA-331/2-01-016**

**TECHNICAL REPORT**

**Source Identification of Lead Contamination  
in the Soil of the Westgate Trailer Park,  
Greer, South Carolina**

**Project No. SP0049 (VP0300, R55)**

**July 3, 2001**

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**Source Identification of Lead Contamination  
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## ABSTRACT

Several different types of analyses were conducted to identify the presence and sources of anthropogenic lead contamination in residential soil adjacent to an automobile battery manufacturer. These analyses included measurements of elemental concentrations and lead isotope ratios in bulk soil samples in addition to individual particle analysis. Analyses were conducted on soil and attic dust from residential areas adjacent to the battery facility; on soil from undisturbed wooded areas adjacent to the battery facility; on soil from a roadside some distance from the battery facility; and samples of soil, process materials, and dust from the battery facility itself.

Analytical results indicated high lead concentrations in the soil of the residential and undisturbed wooded areas, up to 2760 and 3860 mg/kg, respectively. Antimony and tin were important signature elements in bulk soil and individual particle analysis linking lead from the battery facility to lead in the soil of the residential and undisturbed wooded areas. Lead particle size data indicated most of the lead contamination in the residential and undisturbed wooded areas underwent airborne transport. Furthermore, average lead concentrations, lead/antimony ratios, and lead/bromine ratios in bulk soil and results of individual particle analysis indicated most of the lead contamination in the soil of the residential and undisturbed wooded areas originated from the neighboring battery facility. In contrast, most of the lead in roadside soil originated from automobile exhaust.

High variability of lead concentrations over short distances (less than a meter) in residential soil indicated the necessity of remediating the entire soil area or undertaking an extensive soil sampling survey to properly delineate soil areas not requiring remediation. High lead concentrations found in soil to a depth of 15.2 centimeters (6 inches) indicated remediation of residential soil to at least this depth should be considered.

## 1. INTRODUCTION

### 1.1. Basis and Objectives of Study

At the request of the United States Environmental Protection Agency's (EPA) Region 4, the EPA's National Enforcement Investigations Center (NEIC) conducted a study to determine the major sources of suspected lead contamination in the soil of the Westgate Trailer Park in Greer, South Carolina. The study was undertaken because of concerns by the South Carolina Department of Health and Environmental Control (DHEC) that young children living in the Westgate Trailer Park were exhibiting high levels of lead in their blood due to high concentrations of lead in the soil of the trailer park. The identification of major sources and potential responsibility of suspected lead contamination in the trailer park soil would facilitate any necessary remediation of the soil. Lowering high soil lead concentrations in the trailer park would be expected to decrease the potential for high levels of lead in the blood of children living in the trailer park. For these reasons, it was important for NEIC to determine the levels and variability of lead in the soil of the trailer park in addition to determining the major sources of suspected lead contamination. To meet these objectives, samples were collected of soil and attic dust in the Westgate Trailer Park; of soil, dust, and process materials at the adjacent Exide automobile battery manufacturing facility; of soil in undisturbed wooded areas adjacent to the Exide facility and the Westgate Trailer Park; and of soil adjacent to a busy highway 2.4 kilometers (1.5 miles) from the Exide facility. Three different types of data were collected from these samples: bulk elemental composition, individual particle data, and lead isotope ratios. The scientific basis and rationale for collecting these data for source identification are described below along with sampling site descriptions and previous site studies.

### 1.2. Sampling Site Descriptions

Studies such as this with the objective of identifying the source or sources of hazardous substance contamination in the environment are sometimes referred to as source-receptor studies. Contamination of the environment by a hazardous substance occurs when a hazardous substance exists in the environment at concentrations above natural background levels. In these studies, "source" typically refers to the origin or potential origin of a hazardous substance occurring as contamination in the environment. "Source material" refers to material from a source or potential source. "Receptor" typically indicates the area, site, or media where a contaminant material is found after transport from a source. "Receptor media" may be residential soil, undisturbed soil in wooded areas, attic dust, groundwater, surface water, or any contaminated substance. A "non-receptor" area or media indicates an area, such as a background sampling area, or a substance, such as soil or water,

that is negligibly impacted by the contaminant material in question. Non-receptor areas or media may not necessarily represent true "background" since true background in many cases is difficult, if not impossible, to identify.

In this source-receptor study, samples of soil collected from the Westgate Trailer Park were referred to as receptor samples or receptor soil because of the suspected lead contamination in the trailer park soil. Samples of attic dust collected from the Westgate Trailer Park were also referred to as receptor samples because attic dust was expected to contain similar lead contamination if the contamination had undergone airborne (aeolian) transport. Soil samples were also collected from wooded areas with undisturbed soil located adjacent to the Exide facility and the Westgate Trailer Park. These soil samples were also referred to as receptor samples or receptor soils because the wooded areas may have been impacted by lead in a similar manner as the trailer park. The attic dust and undisturbed soil in the wooded areas were expected to contain a more complete record of suspected lead contamination which may have occurred in the area over the past several decades. One of the suspected sources of possible lead contamination in the trailer park soil was the adjacent Exide battery facility. For this reason, samples of soil, dust, and process material collected from the Exide facility were referred to as source samples. These samples were expected to contain the type of lead which was historically present at the Exide facility. Another suspected source of possible lead contamination in the trailer park soil was automobile exhaust. Samples of soil collected adjacent to a busy highway away from the Exide facility were considered non-receptor samples relative to lead from the Exide facility because a negligible impact by Exide facility lead was expected at that location. However, because the roadside soil samples were expected to have been impacted by lead from automobile exhaust, they were considered source samples relative to automobile exhaust. The location of these sites in Greer, South Carolina is shown in Figure 1-1.

### **1.2.1. Description of the Westgate Trailer Park**

The Westgate Trailer Park was developed in the 1960s (Webb, 1997) within the city limits of Greer, South Carolina at the intersection of Old Chick Springs Road and Old Buncombe Road. The location of the Westgate Trailer Park is shown in Figure 1-2. The Westgate Trailer Park was bounded to the northwest by Old Chick Springs Road, to the northeast by Old Buncombe Road, to the southeast by a commercial lot, and to the south by the P&N Railroad (CSX Transportation). Immediately southwest of the Westgate Trailer Park was the Exide facility. Across Old Chick Springs Road and Old Buncombe Road from the trailer park were commercial properties. Across the railroad from the trailer park was an industrial property. The trailer park covered approximately 2 hectares (5 acres) and was separated by standard chain-link fencing from the Exide facility, Old

Chick Springs Road, Old Buncombe Road, the southeast commercial lot, and the railroad. The fence on the Old Buncombe Road side of the trailer park was lined by trees and shrubs 2 to 3 times the height of the fence. The fence on the Exide side of the trailer park was overgrown by vegetation in places up to the top of the fence. There was a slight upwards gradient from the Exide facility to the trailer park and a steep gradient from the trailer park down to the railroad.

There were two entrances into the trailer park on Old Chick Springs Road. From each entrance, a narrow, asphalted street without curbs led southeast to the fence on the south side of the park. The street on the eastern side of the trailer park was approximately 125 meters (410 feet) long and lined on each side by a row of 10 trailers. The street on the western side of the trailer park was approximately 210 meters (689 feet) long and lined on the east side by a row of 15 trailers and on the west by a row of 17 trailers. Trailers had white aluminum siding, no obvious attic spaces, and slightly sloping roofs with rain runoff channeled onto the ground at the corners of the trailers. Yards between trailers were primarily covered with mowed grass with some bare earth parking areas in front of trailers. Bare earth was primarily hard-packed clayey soil. To the east of the west entrance to the trailer park was a small house utilized as the park office. The house had an attic and PVC siding. Peeling paint was not observed in the trailer park, nor were paint chips observed on the ground. The residents of the trailer park included many young children who spent much time playing outdoors.

### **1.2.2. Description of the Exide Facility**

Much of the Exide facility history is given in the following documents: Daniel (1989), Leed (1991), and McInnis (1996). The Exide facility was constructed by previous owners in 1960 in Greer, South Carolina and has had several owners. The original owner, Bowers Battery, changed its name to General Battery and Ceramic Corporation in about 1960 when manufacture of automobile batteries began at the site. In about 1968, the name was shortened to General Battery Corporation. In about 1973, Northwest Industries took over the facility. By May 1987, the Exide Corporation had acquired the facility.

The Exide property was bounded to the north by Old Chick Springs Road, to the northeast by the Westgate Trailer Park, to the southeast by the P&N Railroad, and to the southwest by the King Acres residential subdivision. The location of the Exide property is shown in Figure 1-2. Land uses in the immediate vicinity of the facility included industrial and commercial as well as residential. The Exide property covered approximately 9 hectares (22 acres) and contained one large building of an estimated 9000 square meters (97,000 square feet), several smaller buildings, an abandoned



wastewater lagoon, and a storm water storage tank. The old grid casting area on the east side of the main Exide building was situated within approximately 50 meters (164 feet) of the Westgate Trailer Park fence. Figure 1-2 depicts the Exide facility and surrounding properties

Large areas of mowed grass existed to the northwest and northeast of the main Exide building. Large areas to the northwest, west, south, and southeast of the main Exide building were covered by asphalt. Small areas of asphalt were exposed to or covered by dirt and gravel. At least three baghouses were located outside the main Exide building on the south side. For many years, lead oxide was prepared at the Exide facility in lead pots using the Barton process. A garage door opened directly to the outside from the lead oxide preparation area on the south side of the main Exide building. Lead alloy grids were cast in the old grid casting area in the main Exide building. The old grid casting area on the east side of the main Exide building was an estimated 10 meters (33 feet) high with venting on the roof. At least one personnel door opened from the old grid casting area directly to the outside. Lead paste was made in the pasting area in the main Exide building and sulfuric acid was used in the nearby assembly area. Process materials and dusts inside the main building included a pile of lead oxide powder and debris in the lead oxide operation, debris in the pasting area, dust in the grid casting area, and baghouse dust. Process materials, dusts, and soils at the Exide facility were sampled to characterize lead from the Exide facility for comparison with lead found in the Westgate Trailer Park.

### **1.2.3. Description of Adjacent Wooded Areas**

Adjacent to the Exide facility and Westgate Trailer Park were several wooded areas. These areas included vacant lots in the King Acres Subdivision immediately southwest of the Exide facility and areas immediately south of the Exide facility and Westgate Trailer Park along, and north of, the tracks of the P&N Railroad. The locations of these areas are shown in Figure 1-2. These wooded areas were covered with a variety of trees and undergrowth. Trees in these areas varied in size, but many were as much as 20 centimeters (8 inches) in diameter and 10 meters (33 feet) in height. Also, soil in these areas was comprised of an upper layer of decaying organic material typically several centimeters (2.54 centimeters = 1 inch) thick and frequently overlain by dead leaves. These areas were targeted for soil core sampling due to their immediate proximity to the Exide facility and Westgate Trailer Park and because the trees and undergrowth indicated soil in these areas had not been disturbed for years and probably decades. Undisturbed soil such as this would be expected to collect and preserve air particle fallout over long periods of time thereby creating a record of airborne deposited material over many years.

#### 1.2.4. Description of Roadside Sampling Area

An area along the side of a roadway was chosen to characterize lead from automobile exhaust and regional soil. The area was located along Route 101, approximately 2.4 kilometers (1.5 miles) north of the Westgate Trailer Park and Exide facility. The sampling area was near the intersection of Route 101 and Ansel School Road and the Lake Cunningham Fire Station. The location of this area is shown in Figure 1-1. Route 101 was a major two lane highway into Greer from the north with constant daytime traffic. The highway fed into Old Buncombe Road next to the Westgate Trailer Park. The shoulders of the road where soil core sampling was conducted were covered primarily by grass with scattered areas of exposed clayey soil.

#### 1.2.5. Geology of Area

Greer, South Carolina, is located in the Piedmont on the eastern slope of the Appalachian Mountains at approximately 320 meters (1050 feet) in elevation. Greer is situated over the northeast-trending Inner Piedmont Core geologic structural unit (Bramlett and Griffin, 1978). The two major rock types underlying the area are metamorphic in origin, a mica schist and a biotite gneiss. A saprolite, or soil, overlying these rocks was formed through the in-situ (in-place) chemical weathering of the mica schist and biotite gneiss. The saprolite soil is dark red to light reddish-brown, clay rich, and contains flakes of muscovite mica. Commonly found heavy minerals in the soil and sediments around Greer include: cassiterite ( $\text{SnO}_2$ ), illmenite ( $\text{TiO}_2$ ), monazite (a lanthanum and rare earth phosphate), and zircon ( $\text{ZrSiO}_4$ ) (Jackson and Moore, 1983).

The area around Greer consists of rolling hills where the closest ridge of mountains is approximately 32 kilometers (20 miles) to the northwest and the main ridge of mountains approximately 56 kilometers (35 miles) beyond that. These mountain ridges lie in a northeast-southwest direction and tend to influence wind directions in Greer. Prevailing wind directions in Greer are almost evenly divided between northeast and southwest (NOAA, 1999).

#### 1.3. Previous Studies

Previous studies of the Westgate Trailer Park and Exide facility include a 1989 Site Screening Investigation Report by South Carolina DHEC (Daniel, 1989), a 1996 Preliminary Assessment / Site Inspection by South Carolina DHEC (McInnis, 1996), and a 1997 Remedial Investigation Report by the Fletcher Group, Inc. for Exide Corporation (Webb, 1997). Daniel (1989)

indicated groundwater and surface water at the Exide facility became contaminated by lead and acid due to problems with an unlined wastewater lagoon and waste pretreatment system. In addition, Daniel (1989) claimed soil in the King Acres Subdivision became contaminated by lead due to surface water runoff and concluded there was potential for exposure to contaminated soil, both on-site at the Exide facility and off-site in the King Acres Subdivision. In a response to the 1989 Site Screening Investigation Report, Profit (1990) stated that soil lead concentrations at the Exide facility greater than 2,000 ppm were removed in 1989. McInnis (1996) noted the presence of high levels of lead in the soil of the Westgate Trailer Park and described a limited soil removal action previously taken on the eastern side of the trailer park. The Remedial Investigation by Exide (Webb, 1997) also described the soil removal action and suggested that air emissions from the Exide facility had not contributed to the lead contamination in the soil of the Westgate Trailer Park because recent air monitoring at the facility had not detected high lead emissions. The Remedial Investigation also concluded that surface water runoff did not transport lead to the trailer park because runoff from the Exide facility does not flow in the direction of the trailer park.

#### 1.4. Automobile Battery Manufacturing

Approximately 88% of the reported lead consumption in the United States is currently attributable to the manufacture of lead acid storage batteries (Smith, 1998). Most lead acid storage batteries are produced for use in automobiles and contain an estimated 11.8 kilograms (26 pounds) of lead per unit (EPA, 1995). The nature and manufacture of lead acid storage batteries are described by EPA (1995) and Bullock and Pierson (1998). Lead alloys used in automobile battery manufacturing are described by Prengaman (1998). About half of the lead present in automobile batteries is present as lead alloy grids and about half as a lead oxide paste. Lead in automobile batteries are produced from lead alloy ingots, sheet lead, and lead oxide powder. Battery grids are produced by either casting melted lead alloy ingots into molds or by stamping grids from sheet lead. Common lead alloying elements used in battery grids are antimony, calcium, and tin. Battery grids commonly employ about 1 to 3 weight percent antimony. Lead-antimony alloys are also commonly used in electrodes, connectors, and terminals. Calcium alloyed with lead is used as a stiffening agent in some maintenance free batteries. After battery grids are produced, they are pasted by either positive or negative paste. The main ingredient of the pastes is a finely divided mixture of lead monoxide powder and metallic lead particles referred to as battery oxide. Battery oxide is produced by either the Barton process or the solid state ball mill grinding process. In the Barton process, droplets of lead are oxidized from molten lead in a Barton pot. The resulting lead particles are drop-like or spherical in shape. The solid state ball mill grinding process, produces lead monoxide particles that are flat or flake-like in shape. Both positive and negative pastes are produced by

mixing lead oxide powder, fibers, water, and a sulfuric acid solution to form a paste-like mixture of basic lead sulfates, lead oxide, water, and free lead. Barium sulfate, carbon black, and organic expanders are added to the negative paste. Sometimes, red lead,  $Pb_3O_4$ , is added to the positive paste. Pasting machines force the pastes into the interstices of the grids. After pasting, grids are referred to as plates which are then cured. After curing, plates are assembled by stacking alternating positive and negative plates separated by insulators. These plates are fastened together into an assembly called an element and placed into a battery container. Next, battery containers are filled with a sulfuric acid electrolyte. Finally, during the formation process, cured plates are electrochemically converted into electrode active material.

### **1.5. Data Collection for Source Identification of Lead**

Many types of data are useful for determining the source or sources of contamination in receptor media. In this source-receptor study, bulk chemical composition, lead isotope ratios, and individual particle data were used to identify the primary sources of lead contamination in receptor soil. In addition to collecting these data from receptor soil, these data were also collected from samples of source material. Data from source material for direct comparison with data from receptor media may be very valuable for contaminant source identification. The following sections describe the scientific basis and rationale for collecting bulk elemental composition data, lead isotope ratios, and individual particle data for source identification.

#### **1.5.1. Bulk Elemental Composition**

The usefulness of bulk elemental composition in source identification of contaminant material is based on the uniqueness of the elements contained in the contaminant material. The elemental composition of bulk samples of receptor media may aid in distinguishing sources of a given contaminant when elements associated in contaminant material contain a unique pattern. For this reason, the characterization of the source material of a given contaminant is an important step whenever it is possible. If data from source material is not available, the bulk elemental composition may discern whether certain sources are likely or not. Elemental associations may be studied by examining the ratios of the concentrations of key elements, thereby normalizing variations in individual concentrations. Concentration ratios of trace metals are commonly used in environmental studies (Doctor et al., 1980). Statistical analysis of bulk elemental composition data is sometimes useful in distinguishing contaminant sources in receptor areas. Studies of elemental associations

with lead include studies of automobile exhaust, paint, primary and secondary metal smelters, and battery manufacturers.

Before the phase out of tetraalkyl lead additives in gasoline, lead in automobile exhaust was primarily associated with bromine and chlorine. Lead originating from gasoline combustion was found with bromine and chlorine due to gasoline additives such as 1,2-dibromoethane and 1,2-dichloroethane. Such gasoline additives ensured volatilization of combustion products containing lead. Other elements sometimes associated with lead in automobile exhaust included nitrogen as ammonium, sulfur as sulfate, and phosphorus as phosphate. Many studies have described associations of these elements in automobile exhaust particles (Hirschler and Gilbert, 1964; Pierrard, 1969; Moyers et al., 1972; Robbins and Snitz, 1972; Ter Haar et al., 1972; Habibi, 1973; Paciga et al., 1975; Eldred et al., 1978; Biggins and Harrison, 1979; Dzuby et al., 1979; Harrison and Sturges, 1983; Ganor et al., 1991). One of the most important lead compounds found in automobile exhaust was lead bromochloride,  $PbBrCl$ . Other lead compounds found in automobile exhaust included  $2PbO \cdot PbBrCl$  and various compounds containing both  $NH_4Cl$  and  $PbBrCl$ . Some authors (Biggins and Harrison, 1979; Harrison and Sturges, 1983) found reaction of automobile exhaust particles with atmospheric sulfates resulted in lead sulfate and lead sulfate containing compounds in ambient air polluted by automobile exhaust. Olson and Skogerboe (1975) found lead sulfate to be the predominant lead compound in roadside soils immediately adjacent to heavily traveled roads.

Although the use of lead in paint is now limited due to environmental restrictions, lead chromate was one of the most commonly used pigments in lead based paints (Novotny et al., 1998). Other lead compounds used in paints included lead sulfate, lead molybdate, basic lead chromate, leaded zinc oxide, lead carbonate, basic lead carbonate, lead phosphate, dibasic lead phosphite, and lead silicosulfate. Lead chromate was sometimes used in solid-state solutions with lead sulfate and lead molybdate. Other compounds typically found in paints with lead included titanium dioxide, zinc oxide, and lithopone, a mixture of zinc sulfide and barium sulfate. Due to the use of a combination of these compounds in paint, elemental associations with lead originating from a paint source may include a combination of the following: barium, chromium, molybdenum, phosphorus, sulfur, titanium, and zinc. In a study of lead in urban dust, Linton et al. (1980) found lead in association with titanium near a building with paint exhibiting the same elemental association. Sterling et al. (1998) and Hunt et al. (1992) found lead in house paint associated with titanium, barium, and zinc.

At primary lead and zinc smelters, lead was nearly always associated with cadmium and zinc and was commonly associated with arsenic and copper. Other elements associated with lead from smelters included antimony and silver. Many studies have employed these elemental associations

to identify sources of lead contamination at primary lead and zinc smelters (Buchauer, 1973; Ragaini et al., 1977; Franzin et al., 1979; Lynch et al., 1980; Hogan and Wotton, 1984). For example, Hogan and Wotton (1984) found soils near a primary metal smelter containing elevated levels of copper, lead, and zinc which diminished with distance from the smelter. In addition, antimony and arsenic have been found associated with lead at secondary lead smelters involved in the recycling of automobile batteries (Kimbrough and Suffet, 1995). Also, arsenic has been used with lead in pesticides in the form of lead arsenate (Carapella, 1978). Typically, lead shot has been produced with approximately 0.1 to 2.4 weight percent arsenic (Prengaman, 1998). In addition, lead from coal fired power plants is commonly found in fly ash associated with trace elements including arsenic, bromine, and zinc (Bogdanovic et al., 1995).

As described in the earlier section on automobile battery manufacturing, antimony, calcium, and tin are common lead alloying elements used in battery grids (Bullock and Pierson, 1998). Other lead alloying elements include arsenic, selenium, and silver. Sulfate may be found with lead from battery manufacturing operations due to the basic lead sulfates formed by reaction of sulfuric acid and lead. Barium may also be found with lead from such operations due to the barium sulfate used in the negative battery paste. In addition, silicon dioxide and sodium silicate may be used as gelling agents. Thus, some of the possible elements which might be found with lead from automobile battery manufacturing include antimony, arsenic, barium, calcium, selenium, silicon, silver, sodium, sulfur, and tin.

### 1.5.2. Lead Isotope Ratios

Many elements consist of two or more isotopes. An isotope is one of two or more atoms with the same atomic number but different atomic weights. All isotopes of an element have the same atomic number because they all contain the same number of protons in their nuclei and behave nearly identically in chemical reactions. However, different isotopes of an element have different numbers of neutrons in their nuclei giving them different atomic weights. The element of lead consists of four stable isotopes and several radioactive isotopes, each with a different atomic weight. The stable isotopes of lead with their atomic weights superscripted are:  $^{204}\text{Pb}$ ,  $^{206}\text{Pb}$ ,  $^{207}\text{Pb}$ , and  $^{208}\text{Pb}$ . Because the radioactive isotopes of lead decay very quickly, most of them are not present in useful quantities for studies of lead. An exception is  $^{210}\text{Pb}$  which is used for the determination of sedimentation rates and the age dating of recent sediments.

The first lead isotope analyses were made by Aston (1927 and 1929) followed by analyses showing the relative abundance of lead isotopes by Nier (1938). Many authors since have described

in detail the theories and concepts relating to lead isotope geochemistry as well as variations in the relative abundance of lead isotopes and applications of lead isotopes in geology. A few of these authors are: Bate and Kulp (1955), Cahen et al., 1958; Russell and Fraquhar (1960), Cannon et al. (1961), Brown (1962), Chow and Patterson (1962), Darnley (1964), Stacey et al. (1968), Chow and Earl (1972a), Doe (1970), Zartman and Stacey (1971), Doe and Delevaux (1972), Doe and Stacey (1974), Heyl et al (1974), Zartman (1974), Saager and Koppel (1976), Gulson (1977), Hall et al (1978), Koppel and Grunenfelder (1979), Marvin and Zartman (1984), Smith et al. (1984), and Ayuso et al. (1987) A brief explanation of concepts relating to lead isotope geochemistry is presented below.

Over geologic time, the abundance of the lead isotope,  $^{204}\text{Pb}$ , in the Earth's crust has remained constant because it is not appreciably radiogenic. In other words,  $^{204}\text{Pb}$  does not have a radioactive parent which can produce appreciably more  $^{204}\text{Pb}$ . In contrast, the lead isotopes,  $^{206}\text{Pb}$ ,  $^{207}\text{Pb}$ , and  $^{208}\text{Pb}$ , are radiogenic, being produced through the decay of  $^{238}\text{U}$ ,  $^{235}\text{U}$ , and  $^{232}\text{Th}$ , respectively. Because these lead isotopes are always being formed through radioactive decay, their absolute abundance in the Earth's crust and their abundance relative to  $^{204}\text{Pb}$  has increased over geologic time. Furthermore, increases in the abundance of each of the radiogenic lead isotopes are proportional to the relative decay rates of their radioactive parents. Because these decay rates are different, so are the relative abundances of the radiogenic lead isotopes that are formed over time. As a result, both the original proportions of thorium, uranium, and lead isotopes that formed a lead deposit, as well as the geologic age of that deposit, have a direct effect on the relative abundance of lead isotopes found there. Differences in geologic ages and original proportions of thorium, uranium, and lead isotopes have greatly influenced the large variation of lead isotope abundances found in lead deposits throughout the world. For example, lead ores formed early in geologic time tend to have lower abundances of radiogenic lead ( $^{206}\text{Pb}$ ,  $^{207}\text{Pb}$ , and  $^{208}\text{Pb}$ ) relative to non-radiogenic lead ( $^{204}\text{Pb}$ ) in comparison to lead ores which formed later. Typically, ratios of different lead isotope concentrations are compared to study such variations in lead isotope abundances. Many lead isotope studies concerned with geologic applications employ ratios of radiogenic lead isotopes to  $^{204}\text{Pb}$  because the abundance of  $^{204}\text{Pb}$  does not change with time. However, because it is usually more difficult to measure  $^{204}\text{Pb}$  as precisely as other lead isotopes, due to its small relative abundance (less than 1.7% of crustal lead), some studies employ ratios of the radiogenic lead isotopes to each other, such as  $^{207}\text{Pb}/^{206}\text{Pb}$  and  $^{208}\text{Pb}/^{206}\text{Pb}$ . Such an approach is more common in studies concerned with environmental contamination problems because typical goals of such studies are to distinguish lead from different sources rather than evaluating lead isotope evolution.

Many studies of lead contamination in the environment have applied lead isotope ratios for identifying the source of lead contamination (Chow and Johnstone, 1965; Ault et al., 1970; Chow,

1970, Chow and Earl, 1972b; Rabinowitz and Wetherill, 1972; Chow et al., 1973 and 1975; Shirahata et al., 1980; Gulson et al., 1981; Petit et al., 1984; Hirao et al., 1986; Sturges and Barrie, 1987; Facchetti, 1988, Rabinowitz, 1988; Flegal et al., 1989; Gulson et al., 1989; Mukai et al., 1993 and 1994; Bacon et al., 1996; Farmer et al., 1996 and 1997; Hurst et al., 1996; Moor et al., 1996; Shotyk et al., 1996; MacKenzie et al., 1997; Kersten et al., 1997, Chaudhary-Webb et al., 1998; Marcantonio et al., 1998; Shotyk et al., 1998; Kunert et al., 1999; Monna et al., 1999a and 1999b; Weiss et al., 1999; Dunlap et al., 2000) The use of lead isotope ratios as a tool in source identification is based on the unique lead isotope ratios typically found in a given lead ore body. For example, lead released into the surrounding environment from mine waste and tailings piles are expected to contain the lead isotope ratios of the lead ore at that location. Furthermore, lead isotope ratios remain essentially unchanged after undergoing processing such as smelting, refining, and manufacturing into product materials. Fractionation of lead isotopes (i.e., changes in lead isotope ratios) through physical or chemical processes is negligible. In this way, original lead isotope ratios of a given ore body may be preserved in lead contaminating the environment. However, both primary and secondary lead smelters typically process lead from multiple sources such as ores from different mines, lead wastes from different sources, or a variety of discarded lead products to be recycled. This produces lead products and wastes exhibiting lead isotope ratios which are a mixture of multiple lead ore sources. As a result, lead contamination in the environment typically exhibits these mixtures of lead isotope ratios. In addition, lead contamination in the environment may consist of contributions from a mixture of sources such as paint, gasoline, and industrial wastes and dusts, each of which may contain different lead isotope ratios. Therefore, environmental samples with lead contamination may display linear combinations (i.e., proportional averages) of lead isotope ratios from individual sources. Despite these complications, lead isotope ratios can often provide useful evidence pertaining to the source or sources of lead contamination in environmental media. A common approach in environmental contamination studies is to compare lead isotope ratios of source materials to lead isotope ratios of potential receptor media and probable non-receptor media. For example, an airborne deposited lead contaminant from a given industrial source may alter the lead isotope ratios in near surface residential soil, a potential receptor media, relative to deeper soil, a probable non-receptor media. Lead isotope ratios in deeper soil may correspond to lead isotope ratios in parent rocks, whereas lead isotope ratios in near surface soil may correspond to lead isotope ratios of source material or a value intermediate between lead isotope ratios of source material and parent rock.



### 1.5.3. Individual Particle Analysis

Individual particle analysis characterizes particles by collecting elemental, morphological (shape), textural, and particle size data from individual particles in a sample. This contrasts data collected by bulk elemental analysis because the latter represents an elemental average of all particles in a given sample and does not provide any particle specific information. Characterization of individual particles typically allows classes of particles to be identified and often allows species of the contaminant to be determined. Individual particle data may aid in distinguishing sources of a given contaminant because: (1) elements associated with the contaminant in a particle from a sample of receptor media may exhibit a unique pattern consistent with particles of a given source material, and (2) a particle containing the contaminant may exhibit a morphology (shape) and size consistent with particles of a given source material. If data from source material is not available, individual particle data from receptor media samples may aid in discerning whether certain sources are likely or not. If unique characteristics are found in contaminant particles from receptor samples, these characteristics may provide a "fingerprint" that ties contaminant particles to its source material. In addition, individual particle data may reveal the presence of sources which are not apparent from bulk elemental analysis.

Van Grieken and Xhoffer (1992) and Xhoffer et al. (1992) have described techniques by which individual particle analysis may be conducted. Individual particle analysis may be conducted by a number of techniques including scanning electron microscopy with X-ray emission microanalysis, electron microprobe analysis, laser microprobe mass spectrometry, secondary ion mass spectrometry microanalysis, Raman microprobe analysis, and proton-induced X-ray emission microanalysis. Of these techniques, scanning electron microscopy with X-ray emission microanalysis and electron microprobe analysis are the most similar because both collect elemental data by detecting X-ray emissions from a specimen exposed to an electron beam. These two techniques are also the most commonly used, and scanning electron microscopy with X-ray emission microanalysis is the technique used in this study.

The concepts and methods of scanning electron microscopy and X-ray emission microanalysis are described in great detail by Goldstein et al. (1994) and Lee (1993) and in brief by Heasman and Watt (1989). To conduct individual particle analysis using a scanning electron microscope (SEM), particles from a given sample are placed inside the sample chamber of an SEM. Attached to the SEM is an energy dispersive X-ray spectrometer (EDS) for the detection of X-ray emissions from a given particle to be analyzed. In some cases, a wavelength dispersive X-ray spectrometer (WDS) may also be used. Under vacuum inside the SEM, an electron beam focused to a nanometer scale diameter is scanned across a number of particles, a single particle, or a portion

of a particle. Several types of useful signals emanate from particles exposed to the electron beam, including secondary electrons, backscattered electrons, and X-ray emissions. Secondary electrons emanating from a particle are used to produce on-screen images and digital photomicrographs of the particle. Backscattered electrons emanating from a particle are used to produce compositional images of the particle, both on-screen and for digital photomicrographs. The compositional image produced by backscattered electrons is a visualization of the variation in atomic number in the area scanned by the electron beam. X-ray emissions from a particle are detected by either an EDS or WDS. Detection by an EDS produces a spectrum of the X-ray energies emitted from the area scanned by the electron beam. X-ray energy responses characteristic of a given element indicates its presence in the area scanned by the electron beam. The relative abundance of the elements detected may be determined from the relative intensities of their characteristic X-ray energies. A WDS is more sensitive to and produces a greater resolution of the characteristic X-ray energies detected.

Backscattered electron imaging is useful for locating particles containing lead among particles of soil. In backscattered electron imaging, features having compositions of higher mean atomic number appear brighter. Because lead has a much higher atomic number relative to most other elements typically found in soils, particles containing lead are usually clearly distinguished from other particles in backscattered electron imaging. Secondary electron imaging as well as backscattered electron imaging produce images depicting the morphology, texture, and size of lead containing particles, in addition to textural relationships between particles. Spectra of X-ray emissions from particles containing lead give the elemental composition of the particle.

Data collection on individual particles may be manual or automated by computer control. Although automated data collection is faster and is objective within the constraints of the computer program controlling data collection, less information is typically obtained during data collection. Manual data collection can utilize morphological, textural, and spacial information including textural relationships between particles to optimize data collection in ways a computer program cannot.

Many studies have applied individual particle analysis using scanning electron microscopy with X-ray emission microanalysis or the related technique of electron microprobe analysis to the characterization of lead containing particles from such sources as automobile exhaust, mining waste, smelters, and paint (Ter Haar and Bayard, 1971; Paulson and Ferrell, 1973; Little and Wiffen, 1978; Linton et al., 1980; Post and Buseck, 1984; Heasman and Watt, 1989; Hunt et al., 1992; Steiner et al., 1992; Mahaffy et al., 1998; Sterling et al., 1998; Sobanska et al., 1999). Many of these studies identify sources of lead contamination in house dust and atmospheric dust and aerosol, and some apportion lead contaminants between identified sources.

## 2. METHODS

### 2.1. Sample Collection

In cooperation with the EPA's Region 4 and South Carolina's DHEC, NEIC conducted sampling in Greer, South Carolina of soil and attic dust in the Westgate Trailer Park; of soil, dust, and process materials at the adjacent Exide facility; of soil in undisturbed wooded areas adjacent to the Exide facility and the Westgate Trailer Park; and of soil adjacent to a busy highway 2.4 kilometers (1.5 miles) from the Exide facility. Described below are the sample collection procedures employed.

#### 2.1.1. Soil Core Sampling Procedure

All soil cores were collected in polycarbonate core tubes 15.2 centimeters (6 inches) in length and 5.1 centimeters (2 inches) in diameter by slide hammer coring devices. All soil cores collected remained in the core tubes for shipping and storage. Core tubes with soil cores were placed in resealable plastic bags with printed labels, double bagged, and stored in locked coolers. Soil cores were shipped in secured containers to NEIC's facility and have been maintained in NEIC's custody

All soil cores were collected in sets of four (A to D) to determine the areal extent and variability of lead concentrations in the soil of the area of interest. Soil core locations designated "A" were chosen by methods described below for each group of samples. After the "A" soil core locations were chosen, "B," "C," and "D" soil core locations were selected relative to "A" based on a sampling template constructed with randomly chosen coordinates. The construction of this sampling template is described as follows.

The sampling template was constructed using three pairs of computer generated random numbers. These random numbers represented coordinates of vector angle and length within separate one-third areas of a circular area of soil. The circular area of soil was defined with soil core location "A" at the center and with a radius of 1.52 meters (5 feet) or 0.76 meter (2.5 feet). In this manner, random coordinates located sampling locations for soil cores "B," "C," and "D" within separate one-third areas of a circular area of soil. The relative configuration of "A," "B," "C," and "D" soil core locations are shown in Figure 2-1. This configuration of soil core locations provided sets of four soil cores representing component concentrations in specified areas of surrounding soil. For sets of soil cores sampled using a circle with a radius of 1.52 meters, analytical results represented

concentrations in the soil over an area of 7.3 square meters (79 square feet) For soil core sets sampled using a circle with a radius of 0.76 meter, the area was 1.8 square meters (19.5 square feet)

### **2.1.2. Sampling of Soil in the Westgate Trailer Park**

On May 12, 1997, 80 soil cores (01A to 20D) were collected from the Westgate Trailer Park by NEIC personnel with assistance from EPA Region 4 and South Carolina's DHEC personnel. Soil cores were collected in polycarbonate core tubes, shipped, and stored, as described above.

Locations of 20 soil cores with the designation, "A" (01A to 20A), were chosen based on high lead results from X-ray fluorescence (XRF) analyses conducted in the field by personnel from EPA-Region 4. To determine the areal extent and variability of lead concentrations in the soil, "B," "C," and "D" soil core locations were chosen randomly relative to "A" soil cores, as described below. This resulted in the collection of 20 sets of 4 samples, "A" through "D," which represented separate and specific areas of soil in the trailer park. The locations of soil core "A" from each set of soil cores collected in the Westgate Trailer Park are detailed in Table 2-1a and are shown in Figure 2-2.

Locations of 20 "B," 20 "C," and 20 "D" soil cores (01B to 20B, 01C to 20C, and 01D to 20D) were determined relative to "A" soil core locations using a preconstructed template. The template was constructed with three pairs of computer generated random numbers representing vector angle and length, as described previously. These pairs of random numbers represented randomly selected sample locations for soil cores "B," "C," and "D" within separate one-third areas of the circle with sample "A" at the center and a radius of 1.52 meters (5 feet). The configuration of "A," "B," "C," and "D" soil core locations are shown in Figure 2-1. Obstructions required the distance from soil core "A" to each of soil cores "B," "C," and "D" to be cut in half for soil core sets 01, 05, 14, and 15. In this manner, 16 sample sets of 4 soil cores (A to D) represented component concentrations in the soil over separate and specific areas of 7.3 square meters (79 square feet). For sample sets 01, 05, 14, and 15, the area was 1.8 square meters (19.5 square feet).

### **2.1.3. Sampling of Attic Dust in the Westgate Trailer Park**

On May 14, 1997, NEIC personnel with assistance from EPA Region 4 collected three attic dust samples (96 to 98) from the attic of the frame house located at the front entrance of the Westgate Trailer Park. Attic dust was collected to obtain atmospheric fallout material which had

collected in the attic through side vents. The attic dust likely had accumulated and remained undisturbed since construction of the house. A Royal Dirt Devil Can-Vac™ vacuum cleaner equipped with a Royal Micro-Fresh™ dust collection bag was used to collect the attic dust samples. Although Micro-Fresh™ dust collection bags were manufactured for use with Royal Upright vacuum cleaners, slight modifications were made to the opening of the Micro-Fresh™ bags to fit them to the Royal Dirt Devil Can-Vac™. The entrance to the attic space in the frame house was through a ceiling opening in the hallway closet. Dust located on the framework and vent of the west attic wall on the north side and on floor joists nearby was vacuumed for sample 96. Dust located on the framework of the west wall on the south side and on floor joists nearby was vacuumed for sample 97. Dust located near and on the framework of the entire east wall and on floor joists nearby was vacuumed for sample 98. Because most of the dust in the attic was collected during this sampling, these three samples were considered representative of the dust present in the attic. Invariably some extraneous, unintended material such as vermiculite insulation particles were vacuumed up with the dust sample. Reasonable attempts were made to minimize the contribution of such material. After vacuuming, the entire dust collection bag with contents was removed from the vacuum cleaner and placed in resealable plastic bags, double bagged, and stored in locked coolers. Samples were shipped in secured containers to NEIC's facility and have been maintained in NEIC's custody. Attic dust samples collected in the Westgate Trailer Park are detailed in Table 2-1b. The location of the house from which the attic dust samples were collected and the approximate collection locations of the attic dust samples in the house are shown in Figure 2-2.

Decontamination of the vacuum apparatus prior to sampling consisted of washing the uptake hose and connection between the hose and the dust collection bag with dilute acid and rinsing with distilled, deionized (DDI) water. The Royal Dirt Devil Can-Vac™ was designed with the motor downstream of the dust collection bag, limiting any motor derived contamination. Micro-Fresh™ dust collection bags are rated to retain particles down to 0.1 micrometer ( $3.9 \times 10^{-6}$  inch). The Micro-Fresh™ bags combine a high filtration paper bag with an electrostatically charged fiber liner. Representatives of Royal Dirt Devil indicated retention characteristics for Micro-Fresh™ dust collection bags as follows: 87.5%, 90.5%, 90.7%, 90.7% and 91.5% retention for particles with diameters of 0.1, 0.2, 0.3, 0.4, and 0.5 micrometers, respectively (1 micrometer =  $3.9 \times 10^{-5}$  inch).

#### **2.1.4. Sampling of Soil at the Exide Facility**

On May 13, 1997, 12 soil cores (33A to 35D) were collected near the east side of the main building at the Exide facility with assistance from EPA Region 4 and South Carolina's DHEC

personnel. Soil cores were collected in polycarbonate core tubes, shipped, and stored, as described above

Locations of three "A" soil cores (33A to 35A) were chosen based on high lead results from XRF analyses conducted in the field by EPA-Region 4 personnel. To determine the areal extent and variability of lead concentrations in the soil, "B," "C," and "D" soil core locations were chosen randomly relative to "A" soil cores, as described below. This resulted in the collection of three sets of four soil cores, "A" through "D," which represented separate areas of soil at the Exide facility. The locations of soil core "A" from each set of soil cores are given in Table 2-2a. Locations of soil cores taken from the Exide facility are shown in Figure 2-3.

Locations of three "B," three "C," and three "D" soil cores (33B to 35B, 33C to 35C, and 33D to 35D) were determined relative to "A" soil cores using a preconstructed template. The template was constructed using computer generated pairs of random numbers, as described previously. The pairs of random numbers represented randomly selected sample locations for soil cores "B," "C," and "D" within separate one-third areas of the circle with sample "A" at the center and a radius of 1.52 meters (5 feet). The configuration of "A," "B," "C," and "D" soil core locations are shown in Figure 2-1. In this manner, three sets of four soil cores (A to D) represented component concentrations in the soil over separate areas of 7.3 square meters (79 square feet).

#### **2.1.5. Sampling of Process Materials and Dust at the Exide Facility**

On May 12 and 13, 1997, personnel from NEIC with assistance from South Carolina's DHEC collected 18 samples (21 to 32, 36 to 40, and 90) of process materials and dust from the Exide facility. At the time of sampling, the Exide facility was not operating. Samples of process materials and dust were collected from several different locations including the lead oxide area, the old grid casting area, the pasting area, the baghouses, and various areas on the ground immediately outside the building. Locations of samples are given in Table 2-2b and approximate sampling locations are shown in Figure 2-3. Descriptions of sampled materials follow. Quantities of powdered lead oxide remained in open piles (sample 24) approximately 1/3 meter high (1.1 feet) in the lead oxide area in the south part of the main building. Also found in the lead oxide area were lead melting pots stationed over floor gratings. The lead melting pots (sample 22) and floor gratings (sample 23) were covered in debris. The lead oxide area was accessible from the outside on the south through a large garage door. Process material debris was found in ducts and on the floor in the pasting area (samples 21, 28, 29, 30), centrally located in the main building. Three baghouses located on the south side of the main building still contained process dust (samples 31, 32, 90). Samples of process dust were

collected from on top of wall beams inside the old grid casting area (samples 25, 26, 27). The old grid casting area on the east side of the main Exide building was situated within approximately 50 meters (164 feet) of the Westgate Trailer Park fence. Figure 1-2 depicts this proximity. Dust and debris from various areas on the ground immediately outside the building were also sampled (samples 36 to 40), including the area in front of a door opening directly to the outside from the old grid casting area (sample 37) and the area in front of a door opening to the outside from near the old grid casting area (sample 36). Samples were composites of at least 20 increments collected with small disposable plastic scoops. Samples were placed in gallon-size resealable plastic bags and double bagged. Representatives of Exide were provided with field duplicates collected by NEIC and DHEC personnel. Samples were shipped in secured containers to NEIC's facility after collection and have been maintained in NEIC's custody.

#### **2.1.6. Sampling of Air Particles at the Exide Facility**

Suspended air particles at the Exide facility were collected by South Carolina's DHEC personnel between December 1994 to September 1995. Air particles less than 10 micrometers ( $3.9 \times 10^{-4}$  inch) in size were collected on glass fiber air filters in the high volume air sampler located on the east side of the Exide property adjacent to the Westgate Trailer Park. Strips of the 61 air filters collected during this time period were sent to NEIC from DHEC through EPA Region 4. Air filter strips were either 3.8 by 28 centimeters or 5.7 by 28 centimeters in size (1.50 or 2.24 inches by 11 inches).

#### **2.1.7. Sampling of Soil in Adjacent Wooded Areas**

On May 13 and 14, 1997, 80 soil cores (61A to 67D, 71A to 78D, and 91A to 95D) were collected from wooded areas adjacent to the Exide facility and Westgate Trailer Park by NEIC personnel with assistance from EPA Region 4 and South Carolina's DHEC personnel. These areas included vacant lots in the King Acres Subdivision immediately southwest of the Exide facility and areas immediately south of the Exide facility and Westgate Trailer Park along, and north of, the tracks of the P&N Railroad. Soil cores were collected in polycarbonate core tubes, shipped, and stored, as described previously.

Locations of 20 soil cores with the designation, "A" (61A to 80A), were chosen based on the marked locations of soil samples taken by previous samplers (Webb, 1997). To determine the areal extent and variability of lead concentrations in the soil, "B," "C," and "D" soil core locations were

chosen randomly relative to "A" soil cores, as described below. This resulted in the collection of 20 sets of 4 soil cores, "A" through "D," which represented separate and specific areas of soil in the wooded areas. Locations of soil cores taken from the wooded areas are shown in Figures 2-4 and 2-5.

Locations of 20 "B," 20 "C," and 20 "D" soil cores (61 to 67 B, C, and D; 71 to 78 B, C, and D; and 91 to 95 B, C, and D) were determined relative to "A" soil core locations using a preconstructed template. The template was constructed with three pairs of computer generated random numbers, as previously described. The pairs of random numbers represented randomly selected sample locations for samples "B," "C," and "D" within separate one-third areas of the circle with sample "A" at the center and a radius of 1.52 meters (5 feet). The configuration of "A," "B," "C," and "D" soil core locations are shown in Figure 2-1. Obstructions required the distance from soil core "A" to each of soil cores "B," "C," and "D" to be cut in half for sample sets 93, 94, and 95. In this manner, 17 sample sets of 4 soil cores (A to D) represented component concentrations in the soil over separate and specific areas of 7.3 square meters (79 square feet). For sample sets 93, 94, and 95, the area was 1.8 square meters (19.5 square feet).

#### **2.1.8. Sampling of Roadside Soil**

On May 13, 1997, 80 soil cores (41A to 60D) were collected from along the side of the roadway on Route 101 approximately 2.4 kilometers (1.5 miles) north of the Westgate Trailer Park, with assistance from EPA Region 4 and South Carolina's DHEC personnel. Soil cores were collected in polycarbonate core tubes, shipped, and stored, as described previously.

Locations of 20 soil cores with the designation, "A" (41A to 60A), were based on a systematic sampling plan where the distance from the roadway to the soil core location was approximately 1.2 to 1.5 meters (4 to 5 feet) and the distance between soil core locations was approximately 15 meters (50 feet). Eleven soil cores designated "A" were taken on the west side of the highway and nine were taken on the east side of the highway. To determine the areal extent and variability of lead concentrations in the soil, "B," "C," and "D" soil core locations were chosen randomly relative to "A" soil cores, as described below. This resulted in the collection of 20 sets of 4 samples, "A" through "D" which represented separate and specific areas of soil along the side of the roadway. Locations of soil cores taken from along the side of the roadway are shown in Figure 2-6.



Locations of 20 "B," 20 "C," and 20 "D" soil cores (41B to 60B, 41C to 60C, and 41D to 60D) were determined relative to "A" soil core locations using a preconstructed template. The template was constructed with three pairs of computer generated random numbers representing vector angle and length, as described previously. The pairs of random numbers represented randomly selected sample locations for samples "B," "C," and "D" within separate one-third areas of the circle with sample "A" at the center and a radius of 0.76 meter (2.5 feet). The configuration of "A," "B," "C," and "D" soil core locations are shown in Figure 2-1. A narrow road shoulder width required the distance from soil core "A" to each of soil cores "B," "C," and "D" to be cut in half for all soil core sets. In this manner, all sample sets of four soil cores (A to D) represented component concentrations in the soil over separate and specific areas of 18 square meters (19.5 square feet) along the side of the roadway.

## **2.2. Subsampling and Sample Processing**

Soil cores were subsampled to separate overlying soil litter material from the underlying mineral soil. Soil litter was separated because the potential for human exposure to soil litter is considerably greater than to the underlying mineral soil. Soil core subsampling and processing is described below. The processing and subsampling of process materials and dust from the Exide facility and of attic dust from the Westgate Trailer Park is also described below. Finally, sample preparation for individual particle analysis is also given.

### **2.2.1. Soil Core Subsampling and Grinding**

The subsampling of soil cores consisted of separating the overlying soil litter material from the underlying mineral soil and dividing the mineral soil using disposable wooden spatulas. The soil litter was the top layer in soil cores, where it occurred, and was up to several centimeters thick. Soil litter was rich in decaying organic material and humic substances and was easily differentiated from the underlying mineral soil due to its dark brown to black color contrasting the light brown to dark red color of the mineral soil. Trash and large pebbles were removed and discarded. Not all roadside soils contained a litter layer. In addition to separating and collecting the soil litter layer, the upper 2.5 centimeters (1 inch) of mineral soil immediately underlying the soil litter layer was collected and referred to as the "upper" mineral soil. Mineral soil remaining in soil cores immediately underlying the upper 2.5 centimeters of mineral soil was collected and referred to as the "lower" mineral soil. A similar approach to subsampling soil was used by Hogan and Wotton (1984). Soil litter and mineral soil subsamples were spread out on glass or plastic petri dishes and dried to constant weight

at 50 degrees Celsius in a convection oven. Soil subsamples were ground using a Spex Shatterbox grinder with a steel ring and puck mill. The ring mill was decontaminated by grinding sand in between samples, followed by rinsing with water followed by acetone. Entire soil subsamples were ground to a powder to maximize the representativeness of the aliquots of ground soil used for analysis.

### **2.2.2. Sieving of Attic Dust and Process Materials and Dust**

Samples of process materials and dust from the Exide facility and attic dust from the Westgate Trailer Park did not undergo grinding, but were sieved in preparation for bulk elemental, lead isotope, and individual particle analysis. The purpose of particle size separation was to concentrate particles less than about 150 micrometers ( $5.9 \times 10^{-3}$  inch) in diameter. Particles in this smaller size fraction were most likely to have been airborne transported.

The contents of each dust collection bag containing attic dust from the Westgate Trailer Park (samples 96 to 98) were emptied as completely as possible, weighed, and placed onto a new stainless steel 100 mesh sieve. The sieve was attached to a Rotap™ shaker, and the shaker was run for 5 minutes to process the particle size separation. Both the greater than 150 micrometer size fraction ( $>150 \mu\text{m}$ ) and the less than 150 micrometer size fraction ( $<150 \mu\text{m}$ ), was placed in a clearly labeled glass jar and stored in a locked cooler. Sieves were decontaminated by extensive rinsing with tap water while brushing with a stainless steel brush followed by rinsing with deionized water and reagent grade acetone. The sieves were permitted to dry at ambient room temperature after rinsing with acetone.

The contents of each sample bag of process material or dust from the Exide facility (samples 21 to 32, 36 to 40, and 90) were emptied as completely as possible, weighed, and placed onto a set of new stainless steel sieves, 10, 50, and 100 mesh. Sieves were attached to a Rotap™ shaker, and the shaker was run for 5 minutes to process the particle size separation. Separated size fractions,  $>2$  millimeter (mm), 2 mm to  $300 \mu\text{m}$ , 300 to  $150 \mu\text{m}$ , and  $<150 \mu\text{m}$ , were placed in double resealable plastic bags and stored in a locked cooler. Sieves were decontaminated, as described above.

### **2.2.3. Sample Preparation for Individual Particle Analysis**

Sample preparation for individual particle analysis via scanning electron microscopy involved the following. First, soil samples were chosen for individual particle analysis in a

systematic random manner. Next, squares of double-sided carbon adhesive tape, approximately 6 mm across, were attached to aluminum SEM stubs, 9 mm in diameter. The adhesive side of each SEM stub was then pressed several times against a sample of unground soil litter or against the <150  $\mu\text{m}$  size fraction of a sieved sample. Sieved samples included attic dust from the Westgate Trailer Park and samples of process materials and dusts from the Exide facility. SEM stubs with mounted sample particles were given a thin carbon coating using a Denton Vacuum Desk II carbon coater to prevent charging during examination under the electron beam.

Four of the 61 strips of air filters containing suspended air particles collected on the Exide property adjacent to the trailer park were randomly chosen for individual particle analysis. The four air filter strips were subsampled by cutting out a square piece from each filter approximately 10 mm on a side. Each cut out filter piece was mounted onto a 12 mm diameter carbon SEM stub with clear household cement. To prevent charging during examination, a small amount of carbon paint was applied to the corner of each piece of filter and mounted stubs were given a thin carbon coating, as described above.

### **2.3. Sample Dissolution Procedures**

Samples were prepared for bulk elemental analysis via the following dissolution techniques: potassium hydroxide fusion, nitric acid digestion, and hydrochloric acid digestion. Samples were prepared for lead isotope analysis via hydrochloric acid digestion. These dissolution techniques are summarized in Table 2-3 and are described below along with the associated quality assurance (QA) and quality control (QC) procedures.

#### **2.3.1. Potassium Hydroxide Fusion**

Fusion with potassium hydroxide was conducted on approximately 0.2 gram of sample, which was placed in a 15 mL vitreous carbon crucible after recording the weight of the subsample to three significant figures. To each crucible, 2.0 grams of potassium hydroxide pellets were added. Crucibles were heated to 160 degrees Celsius for at least 1 hour with rotary agitation until all material was satisfactorily digested. Agitation of the crucibles was continued at 460 degrees Celsius for an additional hour. After cooling, sample fusions were rinsed from the crucibles to plastic beakers using 10 mL of concentrated nitric acid. One mL of 30% hydrogen peroxide was added to sample solutions before they were diluted to 100 mL with DDI water. After overnight rotary agitation, sample solutions were vacuum filtered through Nalgene™ disposable, 0.8 micrometer,

cellulose nitrate membrane filtration units and transferred to high density polyethylene bottles for storage

### **2.3.2. Nitric Acid Digestion**

Digestion with nitric acid was conducted on approximately 0.25 gram of sample, which was placed in a 30 mL Teflon™ tube with screw cap after recording the weight of the subsample to three significant figures. To each Teflon™ tube, 10 mL of 50% nitric acid was added. The solutions were heated to 95 degrees Celsius overnight in an air convection oven. After cooling, 20 mL of DDI water were added to each solution. Solutions were vacuum filtered through 0.45 micrometer pore size, cellulose nitrate membranes in disposable Nalgene™ filtration units and diluted to 100 mL with DDI water. Solutions were transferred to high density polyethylene bottles for storage. Each digestate contained 5 mL of concentrated nitric acid per 100 mL of total volume.

### **2.3.3. Hydrochloric Acid Digestion**

Digestion of soil litter and mineral soil with hydrochloric acid was conducted on approximately 1.0 gram of sample, which was placed in a 50 mL glass culture tube with Teflon™ lined screw cap. The weight of the subsample was recorded to three significant figures. For process materials and dusts from the Exide facility, approximately 0.1 gram (rather than 1.0 gram) of sample was used. To each culture tube, 25 mL of concentrated hydrochloric acid and 0.1 mL of 30% hydrogen peroxide were added. Culture tubes were loosely capped and heated for 1 hour at 95 degrees Celsius. After cooling, an additional 0.1 mL of 30% hydrogen peroxide was added, followed by DDI water to bring the final volume to 50 mL. Solids were allowed to settle overnight prior to analysis.

### **2.3.4. QA and QC for Sample Dissolution Procedures**

Quality control and quality assurance for sample dissolution procedures consisted of the fusion, digestion, or extraction of certified reference materials including NIST 2710, replicate samples, blanks, and spiked samples in each batch of samples.

## 2.4. Instrumental Analysis Methods

Samples digested or fused by the above techniques were analyzed for bulk elemental composition by one or more of the following: inductively coupled plasma - optical emission spectroscopy (ICP-OES) with cross-flow nebulization, hydride generation coupled with ICP-OES, inductively coupled plasma - mass spectrometry (ICP-MS) with cross-flow nebulization, and hydride generation coupled with ICP-MS. Although ICP-OES with cross-flow nebulization was used to determine the concentrations of most elements reported in this study, hydride generation coupled with ICP-OES and the ICP-MS techniques were necessary to determine concentrations of key elements by multiple analytical techniques and to determine the concentrations of some important elements not satisfactorily determined by ICP-OES alone. Also determined by ICP-MS were lead isotope ratios. Analysis of bromine was conducted by the United States Geological Survey (USGS) using instrumental neutron activation analysis (INAA). These analytical techniques are summarized in Table 2-3 and are described below along with the associated quality assurance (QA) and quality control (QC) procedures. Finally, scanning electron microscopy with X-ray emission microanalysis was used to conduct individual particle analysis. The procedures used for these analytical techniques are described below.

### 2.4.1. ICP-OES

ICP-OES with cross-flow nebulization was conducted on potassium hydroxide fusions to determine the concentrations of all elements reported except as otherwise noted below, in Table 2-3, and in Appendix A. ICP-OES on potassium hydroxide fusions was also used to confirm lead and tin results by methodologies described below. A Thermo Jarrell Ash ICAP 61-E inductively coupled plasma - optical emission spectrometer with cross-flow nebulization sample introduction was used for concentration measurements. Spectral background and inter-element interference corrections were applied, as appropriate.

### 2.4.2. Hydride Generation / ICP-OES

Hydride generation coupled with ICP-OES was conducted on potassium hydroxide fusions to determine arsenic and to confirm tin by methodology described below. Hydride generation coupled with ICP-OES was also conducted on hydrochloric acid digestions to confirm antimony results by methodology described below. Sample solutions in 25% hydrochloric acid were mixed in line with a solution of 8% potassium iodide and a solution of 4.8% sodium borohydride ( $\text{NaBH}_4$ )

in 0.25 N sodium hydroxide for continuous hydride generation. The mixture was introduced into a gas/liquid separator where hydride gas was separated from the solution. The hydride gas was introduced into a Thermo Jarrell Ash Atomscan 25 inductively coupled plasma - optical emission spectrometer for concentration measurements.

#### **2.4.3. ICP-MS**

ICP-MS was conducted on nitric acid digestions to determine cadmium and lead, and on hydrochloric acid digestions to determine antimony, lead, and silver. A Perkin-Elmer Sciex Elan 6000 inductively coupled plasma - mass spectrometer with cross-flow nebulization was used for concentration measurements. Spectral background and inter-element interference corrections were applied, as appropriate.

#### **2.4.4. Hydride Generation / ICP-MS**

Hydride generation coupled with ICP-MS was conducted on potassium hydroxide fusions to determine tin. Sample solutions in 25% hydrochloric acid were mixed in line with a solution of 2.4% sodium borohydride ( $\text{NaBH}_4$ ) and 0.25 N potassium hydroxide. The mixture was introduced into a gas/liquid separator where hydride gas was separated from the solution. The hydride gas was introduced into a Perkin-Elmer Sciex Elan 6000 inductively coupled plasma - mass spectrometer for concentration measurements.

#### **2.4.5. QA and QC for ICP Analysis Procedures**

Measurement quality control and quality assurance for ICP analysis procedures were conducted during the run of each batch of samples and consisted of the following. Calibration verification was conducted every 10 to 20 measurements to verify the stability of instrument calibration. An independent calibration standard was measured to ensure correct analyte concentrations in the primary calibration standards. Zero-standard or blank calibration verification was conducted every 10 to 20 measurements to verify zero stability. Multiple replicate measurements were made to verify measurement reproducibility. Sample spikes for each analyte were measured to verify accuracy of measurements at the concentration observed for each analyte. Inter-element interference standards were measured to update correction factors for applicable elements and spectral background corrections were applied, as appropriate.

#### 2.4.6. ICP-MS for Analysis of Lead Isotope Ratios

The stable lead isotope ratios,  $^{204}\text{Pb}/^{206}\text{Pb}$ ,  $^{207}\text{Pb}/^{206}\text{Pb}$ , and  $^{208}\text{Pb}/^{206}\text{Pb}$  were measured in hydrochloric acid digestions using ICP-MS for the determination of lead isotope ratios. A Perkin-Elmer Sciex Elan 6000 inductively coupled plasma - mass spectrometer was used with a cross-flow nebulizer and platinum interface cones. Most digestates required dilution with 20% hydrochloric acid to adjust the lead concentrations in the digestates to approximately 75  $\mu\text{g/L}$  of lead. Measurements were made in pulse detector mode only using an RF power of 1200 W, a nebulizer gas flow rate of 0.8 L/min, an integration time of 5525 ms, 221 sweeps/reading, and 9 replicates. Quality control consisted of the digestion and measurement of replicates, measurement of ratios for NIST Standard Reference Material SRM-981 (Common Lead), and digestion and measurement of in-house control environmental samples which had been independently analyzed by thermal ionization mass spectrometry.

#### 2.4.7. Instrumental Neutron Activation Analysis

INAA was conducted by the United States Geological Survey (USGS) for bromine following a procedure described in detail elsewhere (Baedecker and McKown, 1987). One gram samples and standards were irradiated for 8 hours in the USGS-TRIG reactor at a thermal neutron flux of  $2.5 \times 10^{12} \text{ cm}^2/\text{sec}$ . The gamma-ray activity of  $^{82}\text{Br}$  was measured after 7 days of decay at 554.4 and 776.5 keV.

#### 2.4.8. Individual Particle Analysis

Individual particle analysis was conducted to investigate the characteristics of lead bearing particles present in process materials, soils, dusts, and airborne particulate matter. The analyzed characteristics of lead bearing particles included morphology and elemental composition. Analysis was performed by scanning electron microscopy coupled with energy dispersive X-ray spectrometry and wavelength dispersive X-ray spectrometry. The seven sets of particle mounts examined by individual particle analysis included specimens from Westgate Trailer Park soil litter and attic dust; Exide facility soil litter, process materials and dust, and air filters; wooded area soil litter; and roadside soil litter.

Samples were examined under a JOEL JSM 6400 SEM equipped with a PGT PRISM digital EDS and a Noran APEX WDS for elemental microanalysis. For image collection, the acceleration

voltage was set at 20 keV, the beam current was set between 0.1 and 3.3 nA, the working distance was set between 14 and 16 mm, and magnification varied. For analysis by energy dispersive spectrometry, the acceleration voltage was set at 20 keV, the beam current was set between 0.1 and 3.3 nA, the working distance was set between 14 and 16 mm, the take off angle was 30 degrees, and data were collected over a period of 100 seconds. Wavelength dispersive spectrometry was used to determine the presence of abundant oxygen in two different types of lead bearing particles. For this purpose, a NiC crystal was used, the acceleration voltage was set at 10 keV, the beam current was set between 151 and 167 nA, data were collected over a period of 500 seconds over 50 channels, and the working distance was set between 13 and 14 mm.

Individual particle analysis involved the manual examination of backscattered electron images obtained under low magnification to identify particles containing lead. In backscattered electron imaging, particles with higher average atomic number appeared brighter and were easily distinguished from particles with lower average atomic number. Sample mounts were systematically scanned in backscattered electron imaging at a magnification of approximately 1000X. Particles appearing brighter in backscattered electron imaging were analyzed by energy dispersive spectrometry to detect the presence of lead. Particles containing lead were documented by collecting an energy dispersive X-ray spectrum of the particle and an image of the particle in both secondary and backscattered electron modes. Energy dispersive X-ray spectra provided elemental composition of the particles. Backscattered electron images primarily provided compositional information and secondary electron images primarily provided textural and morphological information. Particle size measurements were made from secondary and backscattered electron images of the particles. Particle dimensions measured included the longest particle diameter measurable in the SEM images and the particle diameter perpendicular to the longest diameter. For randomly chosen particles, an EDS spectrum from the area surrounding the particle, and including the particle itself, was collected under identical running conditions for comparison with the particle spectrum.

For trailer park soil litter, all particles found containing lead on 10 of 15 particle mounts from 10 soil litter samples were analyzed and documented. On 5 of those 15 particle mounts of trailer park soil litter, the first 11 to 14 lead bearing particles found were analyzed and documented. Manual searching and analysis and limited resources restricted the amount of time which could be spent on each particle mount. For trailer park attic dust, the first 10 particles found containing lead on a particle mount were analyzed and documented. Particle mounts from three samples of trailer park attic dust were examined. For wooded area soil litter, all particles found containing lead on each of four particle mounts from four soil litter samples were analyzed and documented. For roadside soil litter, each particle found containing lead on each of 10 particle mounts from 10 soil litter samples was analyzed and documented. For air filters, the first 10 particles found containing



lead on each of four particle mounts from four air filters were analyzed and documented. For soil litter from the Exide facility, the first 20 particles found containing lead on each of 3 particle mounts from 3 soil litter samples were analyzed and documented.

Because of the abundance and great size range (<1 to 150  $\mu\text{m}$ , the sieve size limit) of particles containing lead in samples of process materials and dust from the Exide facility, primarily lead bearing particles in a similar size range as that found in receptor samples were analyzed, i.e., generally less than 10 to 20 micrometers. For process materials and dust from the Exide facility, 14 to 20 particles containing lead on each particle mount were analyzed and documented. Particle mounts were examined from 16 samples of process materials and dust from the Exide facility.

The relative net EDS response of elements detected in lead bearing particles provided estimates of the major, minor, and trace element abundance in the particles. Similarly, lead bearing particles were classified based on the relative net EDS response of elements detected in the particles. Particle class determination for the lead bearing particles is described in more detail below in the Results section. From the EDS spectra of the lead bearing particles, the PGT Quant software package provided estimates of the average lead content for particles in the lead particle classes found in the trailer park, wooded areas, and roadside.

## 2.5. Statistical Evaluation of the Data

Averages (arithmetic means), standard deviations, and relative standard deviations were calculated for lead, antimony, iron, scandium, tin, and titanium in the following data sets: (1) 80 soil litter analyses for the trailer park, (2) 12 soil litter analyses for the Exide facility, (3) 80 soil litter analyses for the wooded areas, and (4) 63 soil litter analyses for the roadside. Similarly, averages, standard deviations, and relative standard deviations were calculated for lead in sets of 4 soil litter analyses from the 4 soil cores (A to D) representing circular areas in the following places: (5) 20 sets in the trailer park, (6) 3 sets from the Exide facility, (7) 20 sets in the wooded areas, and (8) 17 sets of 2 to 4 soil litter analyses along the roadside. In the trailer park, two-sided (upper and lower) confidence limits for the mean at 95% confidence and 3 degrees of freedom were calculated for each circular area represented by sets of 4 soil cores. Averages, standard deviations, and relative standard deviations were also calculated for lead in five different types of process materials and dust from the Exide facility. Averages were also calculated for lead concentrations in the soil litter and mineral soil of seven trailer park soil cores selected in a systematic random manner

To determine if a statistical difference could be detected between antimony, lead, and tin concentrations in the soil litter of the trailer park, Exide facility, wooded areas, and roadside, the Mann-Whitney statistical test was conducted. This test was also applied to determine if a statistical difference could be detected between certain populations of lead bearing particles found in trailer park and roadside soil litter. The Mann-Whitney statistical test was useful because it did not assume a normal distribution of data in sample populations. The test compared the medians of two populations of samples by combining the data of the two populations, sorting the data from smallest to largest, and comparing the average ranks of the two populations in the combined data. A "P-value" was determined for the two-sided test where the null hypothesis stated that the two medians were equal. Thus, P-values less than 0.05 indicated, at the 95% confidence level, a statistically significant difference between the medians of the two populations of samples compared. P-values greater than or equal to 0.05 indicated no statistically significant difference between the medians of the two populations at the 95% confidence level.

To determine if a statistical difference could be detected between lead concentrations in the soil litter and respective underlying "lower" mineral soil of the trailer park, a statistical sign test for paired data was conducted. The sign test was useful because it also did not assume a normal distribution of data in sample populations. The sign test took the differences of the paired data and counted the number of values above and below the hypothesized median of zero. A "P-value" was determined where the null hypothesis stated that the median difference between paired data was equal to zero. Thus, P-values less than 0.05 indicated a statistically significant difference at the 95% confidence level between zero and the median difference of the two populations. P-values greater than or equal to 0.05 indicated no statistically significant difference between zero and the median difference of the two populations at the 95% confidence level.

Linear regression analysis, sometimes referred to as correlation analysis, was conducted to evaluate relationships, or correlations, between the concentrations of paired elements in bulk soil samples. Results of linear regression calculations were given as the  $r^2$  statistic, the square of the correlation coefficient,  $r$ . The  $r^2$  statistic and correlation coefficient are indicators of the strength or weakness of a linear relationship between the concentrations of a pair of elements regressed. An  $r^2$  statistic of unity (1) indicates a perfect correlation and an  $r^2$  statistic of zero indicates the absence of any correlation. Thus, an  $r^2$  statistic of 0.80 indicates a relatively strong linear relationship, while an  $r^2$  statistic of 0.20 indicates a relatively weak relationship. The  $r^2$  statistic also represents the proportion of the variability in concentration of one element which may be explained by a linear relationship with the concentrations of the other element. Confidence levels for regression results are based, in part, on the number of data,  $n$ , used in the regression calculation. A confidence level of 99.9% indicates a high level of confidence that a statistically significant relationship exists

between the concentrations of a pair of elements regressed. The sign (+ or -) of the correlation coefficient,  $r$ , indicates a positive or negative correlation. This sign corresponds to a positive or negative slope for the regression line that best fits a linear relationship between the concentrations of a pair of elements. The regression line for a pair of elements shows a positive slope where the plotted concentrations of both elements increase to the right, i.e., plotted data trends upward to the right ( / ). A negative slope is indicated where concentrations of one element increase with a decrease in the concentrations of the other element, i.e., plotted data trends upward to the left ( \ ).

Linear regressions were calculated between lead and other bulk element concentrations; between iron, scandium, and titanium; and between lead and ratios of lead with the latter elements and antimony in the soil litter of the trailer park, Exide facility, wooded areas, and roadside. Linear regressions were also calculated between lead and ratios of lead with iron, scandium, and titanium in the soil litter and "upper" and "lower" mineral soil of the trailer park. The  $r^2$  statistic of the regression results served as an indicator of possible concomitant elements with lead in source and receptor areas. The  $r^2$  statistic also served to distinguish the occurrence and general extent of anthropogenic lead contamination in soil areas. For sample set comparisons, lead concentrations were plotted against selected correlated and uncorrelated elements. Scatter plots of lead, antimony, iron, scandium, tin, titanium, and ratios of these elements were constructed for this purpose. Scatter plots of lead isotope ratios also served this purpose.

### 3. RESULTS

Results of the analytical methods described above are reported in the following sections. The main types of data collected were bulk elemental composition, individual particle data, and lead isotope ratios. Data results reported here were supported by the results of the quality control and quality assurance procedures described above. QA and QC results for reported data were within acceptable and appropriate limits, including satisfactory recoveries of metals in certified reference materials.

#### 3.1. Bulk Elemental Composition

Results of bulk elemental analyses of soil litter from the Westgate Trailer Park, Exide facility, wooded areas adjacent to the Exide facility and trailer park, and from roadside soil are reported in Appendix A. Also reported in Appendix A are the results of bulk elemental analyses of mineral soil and attic dust from the Westgate Trailer Park as well as the results of bulk elemental analyses of process materials and dust from the Exide facility. A summary of analytical results of the elements most important to the objectives of this study are presented below. These elements include lead because lead is the contaminant of concern in the trailer park and antimony and tin because of their association with lead in Exide soil and process dust. The association of antimony and tin with lead in Exide soil and process dust is described later in the Discussion section of the report.

##### 3.1.1. Lead in the Soil Litter in the Westgate Trailer Park

Results of ICP-MS on nitric acid digestions for lead concentrations in the soil litter in the Westgate Trailer Park are reported in Table 3-1 and summarized in Table 3-2. ICP-MS on nitric acid digestions was the primary analytical technique for lead in trailer park soil litter. Confirmation of these results was obtained by ICP-OES on potassium hydroxide fusions. ICP-MS and ICP-OES results were in good agreement where 69% of results were within a relative percent difference of approximately 10, and 99% of results were within a relative percent difference of approximately 20.

Locations of the lead concentrations in the soil litter of the Westgate Trailer Park are displayed in Figure 3-1. For all 80 soil cores collected, lead concentrations averaged 812 mg/kg and ranged from 287 to 2760 mg/kg with a relative standard deviation of 63% (Tables 3-1 and 3-2). Variations in average lead concentrations between circular areas represented by the 20 soil core sets collected in the trailer park were shown by the range and relative standard deviations (RSD) of the

20 average lead concentrations of each set. The range of these average lead concentrations was 356 mg/kg (sample set 17A-17D) to 1925 mg/kg (sample set 09A-09D) with a relative standard deviation of 58%. In addition, variations of lead concentrations within the circular areas of soil litter were represented by the range and relative standard deviations of the four lead concentrations within each set. For example, lead concentrations in sample set 10A-10D ranged from 549 to 1310 mg/kg with the highest relative standard deviation of 49%. Lead concentrations in sample set 20A-20D showed variations from 485 to 522 mg/kg with the lowest relative standard deviation of 3%. However, within sample sets including lead concentrations as low as 321 mg/kg (sample set 11A-11D; 321 to 876 mg/kg), variations as great as 47% relative standard deviation were found.

### **3.1.2. Lead in the Mineral Soil in the Westgate Trailer Park**

Results of ICP-OES on potassium hydroxide fusions for lead concentrations in the soil litter and in the “upper” and “lower” mineral soil of seven soil cores in the Westgate Trailer Park are reported in Table 3-3a. The seven soil cores were selected in a systematic random manner for subsampling and analysis of the underlying mineral soil. The soil litter was the top layer in soil cores, rich in decaying organic material and humic substances, and dark brown to black in color. The soil litter in these seven soil cores varied in thickness from 0.5 to 7 centimeters (0.2 to 2.8 inches) (Table 3-3b). The “upper” mineral soil consisted of the upper 2.5 centimeters (1 inch) of mineral soil immediately underlying the soil litter layer. The “lower” mineral soil consisted of the mineral soil immediately underlying the upper 2.5 centimeters of mineral soil and extending to the bottom of the 15.2 centimeter (6 inch) soil core. Both the “upper” and “lower” mineral soil were light brown to dark red in color, clay mineral rich, and contained flakes of muscovite mica. To provide consistency in comparing lead concentrations between the soil litter and underlying mineral soil layers, results for trailer park soil litter by ICP-OES on potassium hydroxide fusions are reported in Table 3-3a although lead results by ICP-MS on nitric acid digestions were reported above as the primary soil litter results. This was necessary because nitric acid digestions were not available for the trailer park mineral soil, and it was reasonable because lead results by ICP-OES on potassium hydroxide fusions were not distinguishable from lead results by ICP-MS on nitric acid digestions.

Of the soil litters in these seven soil cores, lead concentrations averaged 1110 mg/kg and ranged from 330 to 2330 mg/kg with a relative standard deviation of 71%. For the seven “upper” mineral soil analyzed, lead concentrations averaged 880 mg/kg and ranged from 240 to 1980 mg/kg with a relative standard deviation of 86%. Of the seven “lower” mineral soil analyzed, lead concentrations averaged 381 mg/kg and ranged from 100 to 1040 mg/kg with a relative standard

deviation of 84%. These results indicated the presence of high concentrations of lead, up to 1040 mg/kg, as deep as 15.2 centimeters (6 inches) in the soil in the trailer park.

### **3.1.3. Lead in the Attic Dust in the Westgate Trailer Park**

Results of ICP-MS on hydrochloric acid digestions for lead concentrations in the 3 attic dust samples were 4060 (sample 98), 15,700 (sample 97), and 26,200 (sample 96) mg/kg, averaging 15,300 mg/kg. These results showed the presence of percent level concentrations of lead in the attic dust. The highest concentrations of lead (samples 96 and 97) were on the west side of the attic and were approximately 4 to 6 times higher than on the east side of the attic (Figure 3-1). Confirmation of these results was obtained by ICP-OES on potassium hydroxide fusions. ICP-MS and ICP-OES analyses were in good agreement within a relative percent difference of 10 for all three results.

### **3.1.4. Lead in the Soil Litter at the Exide Facility**

Results of ICP-MS on hydrochloric acid digestions for lead concentrations in the soil litter at the Exide facility are reported in Table 3-4 and summarized in Table 3-2. Confirmation for these results was obtained by ICP-OES on potassium hydroxide fusions. ICP-MS and ICP-OES results were in good agreement where 75% of results were within a relative percent difference of 10, and all 12 of the results were within a relative percent difference of 15.

Figure 3-2a displays the locations of the lead concentrations in the soil litter at the Exide facility. For all 12 soil cores collected, lead concentrations averaged 16,100 mg/kg and ranged from 1260 to 66,600 mg/kg with a relative standard deviation of 133% (Tables 3-2 and 3-4). These results showed not only a large variability in lead concentrations in the soil litter at the Exide facility, but the presence of extremely high concentrations of lead, up to 66,600 mg/kg, much higher than found in the neighboring trailer park.

### **3.1.5. Lead in Process Materials and Dust at the Exide Facility**

Results of ICP-MS on hydrochloric acid digestions for lead concentrations in process materials and dust from the Exide facility are shown in Figure 3-2b and reported in Table 3-5. Sample locations included the lead oxide area, the old grid casting area, the pasting area, the baghouses, and various areas on the ground immediately outside the building. The specific locations

of samples were given previously (Table 2-2b). Confirmation of these results was obtained by ICP-OES on potassium hydroxide fusions. ICP-MS and ICP-OES analyses were in good agreement where 67% of results were within a relative percent difference of 10, and all 18 of the results were within a relative percent difference of 20.

Lead concentrations averaged nearly 82% by weight in samples of process material and debris from the lead oxide area with a relative standard deviation of 4%. In samples of dust from the old grid casting area, lead concentrations averaged over 19% by weight with a relative standard deviation of 45%. For the pasting area, lead concentrations averaged approximately 79% by weight with a relative standard deviation of 8%. In the baghouse dust, lead concentrations averaged nearly 80% by weight with a relative standard deviation of 6%. For the various areas on the ground immediately outside the building, lead concentrations varied from nearly 2% to approximately 42% by weight.

#### **3.1.6. Lead in the Soil Litter in the Adjacent Wooded Areas**

Results of ICP-MS on hydrochloric acid digestions for lead concentrations in the soil litter of the adjacent wooded areas are reported in Table 3-6 and summarized in Table 3-2. Confirmation of these results was obtained by ICP-OES on potassium hydroxide fusions. ICP-MS and ICP-OES analyses were in good agreement where 70% of results were within a relative percent difference of approximately 10, and 94% of results were within a relative percent difference of approximately 20.

Figures 3-3 and 3-4 display the locations of the lead concentrations in the soil litter of the adjacent wooded areas. For all 80 soil cores collected, lead concentrations averaged 952 mg/kg and ranged from 101 to 3860 mg/kg with a relative standard deviation of 79% (Tables 3-2 and 3-6). These results showed not only a large variability in lead concentrations in the soil litter in the adjacent wooded areas, but the presence of high concentrations of lead, up to 3860 mg/kg. Furthermore, these results were similar to those found in the soil litter in the trailer park where the average, range, and relative standard deviation were slightly greater in the wooded areas.

#### **3.1.7. Lead in the Roadside Soil Litter**

Results of ICP-MS on hydrochloric acid digestions for lead concentrations in the soil litter of the roadside soils are reported in Table 3-7 and summarized in Table 3-2. Confirmation of these results was obtained by ICP-OES on potassium hydroxide fusions. Because most of the ICP-OES

results for the roadside soil litter were near the detection limit where greater analytical variability is typical, comparison of these results to ICP-MS results could be expected to show slightly greater variability than results well above the detection limit. Taking this into account, ICP-MS and ICP-OES results were in good agreement where 56% of results were within a relative percent difference of 20, 95% of results were within a relative percent difference of 50, and the averages of the two methods compared with a relative percent difference of approximately 9.

Figure 3-5 displays the locations of the lead concentrations in the soil litter of the roadside soils. For all 63 soil cores collected with a soil litter layer, lead concentrations averaged 167 mg/kg and ranged from 25 to 568 mg/kg with a relative standard deviation of 76%. These results showed lower levels of lead in the soil litter of the roadside soils compared to the Exide facility, trailer park, and wooded areas.

### 3.1.8. Antimony

Results of ICP-MS on hydrochloric acid digestions for antimony concentrations in soil litter in the Westgate Trailer Park, Exide facility, wooded areas, and roadside are given in Appendix A and summarized in Table 3-2. Also, antimony results for the trailer park attic dust by the above method are given in Appendix A. Random confirmation of antimony results in the trailer park soil litter was obtained by hydride generation coupled with ICP-OES on hydrochloric acid digestions and by satisfactory recoveries of antimony in certified reference materials.

Antimony concentrations in soil litter at the Exide facility averaged 105 mg/kg with a relative standard deviation of 153%. In the soil litter of the trailer park, antimony concentrations averaged 4.73 mg/kg with a relative standard deviation of 56%. In the soil litter of the wooded areas, antimony concentrations averaged 7.60 mg/kg with a relative standard deviation of 88%. For soil litter collected along the roadside, antimony concentrations averaged 0.82 mg/kg with a relative standard deviation of 182%. Soil core locations in all areas were given in Figures 2-2 to 2-6. Antimony concentrations in the trailer park attic dust ranged from 21.6 to 105 mg/kg.

Sample locations of process materials and dust from the Exide facility included the lead oxide area, the old grid casting area, the pasting area, the baghouses, and various areas on the ground immediately outside the building. These sample locations were given previously (Table 2-2b and Figure 2-3). Antimony concentrations in samples of process materials and dust from the Exide facility are given in Table 3-5 and Appendix A. High antimony concentrations were found in dust samples from the old grid casting area and in samples of debris from the various areas on the ground



immediately outside the Exide facility building. Antimony concentrations averaged 3040 mg/kg in samples of dust from the old grid casting area with a high of 3620 mg/kg. In samples of debris from the various areas on the ground immediately outside the building, antimony concentrations averaged 1270 mg/kg, ranging as high as 4260 mg/kg.

### 3.1.9. Tin

Results of ICP-MS on hydride generation of potassium hydroxide fusions for tin concentrations in soil litter of the Westgate Trailer Park, Exide facility, wooded areas, and roadside are given in Appendix A and summarized in Table 3-2. Also, tin results for the trailer park attic dust by the above method are given in Appendix A.

Confirmation of tin results for trailer park soil litter was obtained by hydride generation coupled with ICP-OES on potassium hydroxide fusions and by satisfactory recoveries of tin in certified reference materials. Although many of the results were near the detection limits by both methods, ICP-MS and ICP-OES results were in good agreement where 75% of results were within a relative percent difference of 20, 93% of results were within a relative percent difference of 30, and the averages of the two methods compared with a relative percent difference of 10.

Confirmation of the higher tin concentrations in Exide soil litter and Exide process materials and dust was obtained by ICP-OES without hydride generation on potassium hydroxide fusions and by satisfactory recoveries of tin in certified reference materials. These results for tin in Exide process materials and dust were also in good agreement where the averages of the two methods compared with a relative percent difference of 4. In addition, these results for tin in Exide soil litter were in good agreement where the averages of the two methods compared with a relative percent difference of 12.

Tin concentrations in soil litter at the Exide facility, averaged 91 mg/kg with a relative standard deviation of 119%. In soil litter in the trailer park, tin concentrations averaged 12.0 mg/kg with a relative standard deviation of 43%. Tin concentrations in soil litter in the wooded areas averaged 10.9 mg/kg with a relative standard deviation of 44%. For soil litter collected along the roadside, tin concentrations averaged 5.7 mg/kg with a relative standard deviation of 29%. Soil core locations were given in Figures 2-2 to 2-6. Tin concentrations in the trailer park attic dust ranged from 21 to 66 mg/kg.

Sample locations of process materials and dust from the Exide facility included the lead oxide area, the old grid casting area, the pasting area, the baghouses, and various areas on the ground immediately outside the building. Sample locations were given previously (Table 2-2b and Figure 2-3). Tin concentrations in samples of process materials and dust from the Exide facility are given in Table 3-5 and Appendix A. High tin concentrations were found in dust samples from the old grid casting area and in samples of debris from the various areas on the ground immediately outside the Exide facility building. Tin concentrations in samples of dust from the old grid casting area averaged 1360 mg/kg with a high of 2490 mg/kg. In samples of debris from the various areas on the ground immediately outside the building, tin concentrations averaged 1460 mg/kg, ranging as high as 5920 mg/kg.

#### **3.1.10. Bromine**

Results by INAA for bromine are given in Appendix A and are summarized in Table 3-2. Bromine concentrations were determined in soil litter samples from the trailer park, Exide facility, wooded areas, and roadside. Due to resource constraints, approximately every other soil litter sample from the trailer park, wooded areas, and roadside was chosen for analysis. Bromine concentrations in the soil litter of the Westgate Trailer Park averaged 8.50 mg/kg with a relative standard deviation of 39%. At the Exide facility, bromine concentrations in the soil litter averaged 5.43 mg/kg with a relative standard deviation of 47%. Bromine concentrations in the soil litter in the wooded areas averaged 6.70 mg/kg with a relative standard deviation of 51%. Finally, in the roadside soil litter, bromine concentrations averaged 12.0 mg/kg with a relative standard deviation of 63%.

### **3.2. Lead Isotope Ratios**

Results of ICP-MS on hydrochloric acid digestions for the determination of lead isotope ratios,  $^{204}\text{Pb}/^{206}\text{Pb}$ ,  $^{207}\text{Pb}/^{206}\text{Pb}$ , and  $^{208}\text{Pb}/^{206}\text{Pb}$ , are reported in Appendix B. Results included analysis of soil litter from the Westgate Trailer Park, the Exide facility, wooded areas adjacent to the Exide facility, and roadside soils. Results also included analysis of attic dust in the Westgate Trailer Park and process materials and dust at the Exide facility.

Sixty-six determinations of the lead isotope ratios in standard material, NIST SRM-981, were made at regular intervals during analysis of the sample materials listed above. Measurements of the lead isotope ratios,  $^{204}\text{Pb}/^{206}\text{Pb}$ ,  $^{207}\text{Pb}/^{206}\text{Pb}$ , and  $^{208}\text{Pb}/^{206}\text{Pb}$  in SRM-981 were in good agreement with

certified values, falling within 0.3% on average. The relative standard deviation of these measurements were also within 0.3%, consistent with results obtained by Halicz et al. (1996).

### 3.3. Individual Particle Analysis

Individual particle analysis was conducted on lead bearing particles in seven sets of samples including soil litter from soil cores collected in the Westgate Trailer Park, at the Exide facility, in wooded areas adjacent to the Exide facility, and in roadside soil. Individual particle analysis was also conducted on lead bearing particles in trailer park attic dust, Exide air filters, and Exide process materials and dust. Results of individual particle analysis were comprised primarily of spectra from energy dispersive X-ray spectrometry and particle images from scanning electron microscopy. EDS spectra provided the elemental composition of lead bearing particles. In addition, EDS spectra provided estimates of the major, minor, and trace element abundance in lead bearing particles based on the relative net EDS response. SEM images included secondary and backscattered electron images of the particles. Secondary electron images generally provided textural, morphological, and particle size information, and backscattered electron images primarily provided compositional information. Both types of images contained calibrated scales for particle size measurements including the longest particle diameter measurable in the images and the particle diameter perpendicular to the longest diameter. Elemental composition and abundance and particle size data for all lead bearing particles analyzed were tabulated and are given in Appendix C. Lead bearing particles were classified based on the relative net EDS response of antimony, barium, chlorine, chromium, copper, lead, manganese, nickel, phosphorous, tin, sulfur, and zinc, as well as iron where present in major abundance. The frequency of lead bearing particles in each particle class for each of the seven sample sets examined is summarized in Table 3-8. This approach to particle classification was similar to those described by Heasman and Watt (1989), Hopke (1991), and Johnson and McIntyre (1983).

Other elements such as aluminum, bromine, calcium, potassium, silicon, and titanium, as well as the presence of iron in minor or trace abundance were not considered useful for particle class determination due to commonly encountered interference from these elements. Interference from these elements was suspected as a result of their common presence in material adjacent to or surrounding the smaller, micrometer scale, lead bearing particles. Micrometer scale lead bearing particles were common in the soil specimens analyzed. Interference from surrounding material was a greater concern for smaller lead bearing particles because of limitations on the minimum material excitation volume by the electron beam. For many of these particles, an X-ray spectrum from the area surrounding and including the particle was collected for comparison with the spectrum of only

the particle. Results of these analyses indicated that EDS responses for aluminum, calcium, potassium, silicon, titanium, and iron were unreliable for particle characterization and, therefore, were not used to define particle classes. This was despite the possibility that some of these elements may have been present in some lead bearing particles. Furthermore, an overlap in the responses for aluminum and bromine in EDS spectra prevented these elements from being distinguished in the particles analyzed.

Eleven general groupings of particle classes of lead bearing particles were identified (Table 3-8). These general class groupings included: antimony or tin rich (classes 1-4), lead rich containing EDS detectable antimony and/or tin (classes 10-19), lead rich containing EDS detectable copper and/or zinc but not antimony and/or tin (classes 20-24), lead rich but not containing EDS detectable antimony, copper, tin, and/or zinc (classes 30-31), lead rich containing EDS detectable barium (classes 40-45), manganese rich or lead rich containing EDS detectable manganese (classes 50-55), lead rich containing EDS detectable chloride but not barium and/or manganese (class 60), lead rich containing EDS detectable chromium (class 70), copper rich (classes 80-82), lead rich containing EDS detectable sulfur (class 90), and iron rich (class 100). These general class groupings were subdivided into more specific particle classes based on the EDS detection of additional elements such as antimony, chloride, copper, phosphorous, tin, and zinc.

Lead bearing particles found in soil litter from the trailer park primarily included: lead rich particles containing antimony, tin, and a trace of copper; and lead rich particles containing phosphorous and a trace of copper. Also, wavelength dispersive spectrometry detected the presence of oxygen as a major constituent in lead rich particles containing copper and phosphorous but did not detect the presence of oxygen in lead rich particles containing antimony, tin, and copper. Lead bearing particles found in attic dust from the trailer park primarily included lead rich particles containing a trace of copper.

Lead bearing particles found in process materials and dust from the Exide facility primarily included: lead rich particles containing antimony, tin, and a trace of copper; lead rich particles containing a trace of copper; and lead rich particles. Lead bearing particles found in soil litter from the Exide facility primarily included: lead rich particles containing antimony, tin, and a trace of copper (class 10, Figure 3-6a); lead rich particles containing a trace of copper; and lead rich particles containing phosphorous and a trace of copper (class 21, Figure 3-6b). Lead bearing particles found in air filters from the Exide facility primarily included lead rich particles

Lead bearing particles found in soil litter from the wooded areas primarily included lead rich particles containing antimony, tin, and a trace of copper. Lead bearing particles found in soil litter

from the roadside primarily included: lead rich particles containing manganese; and copper rich particles containing zinc and lead (class 80, Figure 3-6c).

Estimates of the average lead content for particles in the lead particle classes found in the trailer park, wooded areas, and roadside were determined from EDS spectra and are given in Table 3-9 in weight percent. These estimates were based on the relative net EDS response for those elements determined to be present in the particles and used to define particle classes, as described above. In addition, stoichiometric oxygen was included in those particle classes which likely occurred as oxides and not metallic alloys. The average lead content in particles of a given particle class and receptor soil was considered the best estimate of the lead content in an individual lead particle. This was because EDS spectra were collected from non-polished particle surfaces, particles surrounded by a soil matrix, and particles approaching and surpassing in size the minimum excitation volume of the electron beam. The effects of any interferences and non-uniform spectral responses were reduced by normalizing results to those elements used to define the lead particle classes and averaging the results for each particle class in a given receptor area.

The majority of lead bearing particles found in all sample sets were irregular in shape. Less common were blocky and spheroid or ovoid shaped lead bearing particles. Lead bearing particles in the soil litter of receptor areas averaged 4.4 to 5.3 micrometers in size. Particle size data is given in Appendix C and a summary of particle size data for the lead bearing particles examined in all sample sets is given in Table 3-10.

Additional findings of individual particle analysis included the observation of several heavy mineral types in soil samples. The most commonly observed heavy mineral grains were: cassiterite ( $\text{SnO}_2$ ), ilmenite/rutile ( $\text{TiO}_2$ ), monazite (a lanthanum and rare earth phosphate), and zircon ( $\text{ZrSiO}_4$ ). These minerals were consistent with regional geologic descriptions by Jackson and Moore (1983) and Frazier and Snipes (1967).

## **4. DISCUSSION**

Data results reported above showed the presence of high concentrations of lead in the soil litter in much of the Westgate Trailer Park with an average of 812 mg/kg of lead and a range up to 2760 mg/kg. These high lead concentrations suggested the presence of lead contamination in the trailer park and were consistent with results reported for the trailer park by McInnis (1996). Furthermore, lead concentrations in the soil litter at the Exide facility indicated the presence of extremely high concentrations of lead, up to 66,600 mg/kg, much higher than found in the neighboring trailer park, suggesting even greater lead contamination in Exide soil litter. The bulk elemental concentrations, lead isotope ratios, and individual particle data of source, receptor, and non-receptor samples were examined for the following reasons: (1) to verify the presence of lead contamination in the soil in the trailer park, (2) to suggest recommendations for the extent of soil remediation in the trailer park, (3) to determine the major source(s) and mode(s) of transport of suspected lead contamination in the soil in the trailer park, and (4) to apportion responsibility(ies) for suspected lead contamination.

### **4.1. Lead Contamination in the Westgate Trailer Park and Other Areas**

As reported above, high concentrations of lead were found in the soil litter in much of the Westgate Trailer Park, suggesting the likely presence of lead contamination there. Furthermore, because dust in house attics generally accumulates over the life of the house and typically remains undisturbed, the very high levels of lead found in the attic dust in the trailer park also indicated the trailer park had been exposed to lead contamination. To identify lead concentration trends with depth consistent with contamination, soil litter in the trailer park was compared to the underlying mineral soil. To further explore if lead concentrations in the trailer park soils were the result of contamination, the bulk elemental composition of soil litter from the trailer park, the Exide facility, the adjacent wooded areas, and the roadside soil were examined. For all areas, lead concentrations were compared to naturally occurring elements to determine the general extent to which lead present in the soil litter may have been attributable to anthropogenic contamination.

#### **4.1.1. Soil Litter to Mineral Soil Comparisons in the Trailer Park**

Measurements of soil depth were presented previously (Table 3-3b) for the seven soil cores selected in a systematic random manner for subsampling and analysis of the underlying mineral soil. The soil litter layer was the upper soil layer rich in decaying organic material and humic substances.

Immediately underlying the soil litter was mineral soil where the "upper" mineral soil consisted of the upper 2.5 centimeters (1 inch) of mineral soil. The "lower" mineral soil consisted of the mineral soil immediately underlying the upper 2.5 centimeters of mineral soil and extended to the bottom of the 15.2 centimeter (6 inch) soil core. The measurements indicated a wide variation in the thickness of the soil litter layer in the trailer park, from 0.5 to 7 centimeters (0.2 to 3 inches) thick.

Although lead concentrations varied widely in the soil litter and mineral soil of these seven trailer park soil cores (Table 3-3a), results showed a clearly decreasing trend in lead concentrations with depth of the soil in the trailer park. On average, lead was nearly 3 times greater in the soil litter than in the "lower" mineral soil. However, these results also indicated the presence of high concentrations of lead, up to 1040 mg/kg, as deep as 15.2 centimeters (6 inches) in the soil in the trailer park.

Lead concentrations in trailer park soil litter and respective "lower" mineral soil were compared by a statistical sign test for paired data described in more detail above in the Methods section. The sign test showed a statistically significant ( $P = 0.023$ ) difference in concentrations of lead between soil litter and respective "lower" mineral soil based on the median difference of the two populations at the 95% confidence level. A P-value less than 0.05 indicated a statistically significant difference at the 95% confidence level between zero and the median difference of the two populations. This result agreed with observations of the data described above, indicating an enrichment of lead in the trailer park soil litter relative to the "lower" mineral soil. Enrichment of the soil litter in the trailer park with lead was consistent with anthropogenic contamination since a concentration gradient was much less likely to be observed for naturally occurring lead.

#### **4.1.2. Comparison of Lead to Naturally Occurring Elements**

The concentration of many naturally occurring elements common in soil may be considered constant for a given area relative to any industrial or agricultural contamination. This assumes such elements are not subject themselves to distribution in the environment from industrial or agricultural activities. Under such conditions, it may be reasonable to use such elements as a reference point to distinguish contamination. To distinguish between soils contaminated by lead and soils which were not, Seeley et al. (1972) selected the ratio of lead to titanium for correlation with the concentration of lead. Titanium was selected because it is widely distributed in nature in silicate minerals and soil and because it was not being used on a widespread industrial basis.

White and Tittlebaum (1985) also recommended the use of metal pair ratios in conjunction with metal concentrations in determining the presence of contamination in sediments. To this end, several metal to iron ratios were inspected, including the lead to iron ratio. In addition, regression analysis was performed to determine the relationship of various metals in sediment cores. Regression analysis was also used by Andresen et al (1980) to assess relationships among metal concentrations in forest soils including lead, copper, and zinc. White and Tittlebaum (1985) also found metal concentrations in background sediment to be very consistent. Scandium was used by Ragaini et al (1977) to normalize variations in metal contamination to the abundance of soil components. Scandium was used because no other reasonable source of scandium but the soil was known. Elements which varied with scandium also were considered to be soil derived.

Because determining the relationship of lead to other elements in soil has been shown to be helpful in verifying lead as a contaminant component of soil, regression calculations were performed on lead concentrations and the concentrations of other elements in the soil litter in each of the four soil areas sampled. These elements included some typically naturally occurring elements such as those mentioned above, iron, scandium, and titanium. Results of the linear regression calculations are given in Table 4-1 as  $r^2$ , the square of the correlation coefficient,  $r$ .

The  $r^2$  values in Table 4-1 revealed a number of elements with very weak to no correlation with lead in the four soil areas. These elements included iron, scandium, and titanium. Although a statistically significant correlation occurred between lead and scandium in the roadside soil at the 99.9% confidence level, the relationship was rather weak, as indicated by the relatively low  $r^2$  value ( $r^2 = 0.24$ ). Scatter plots of lead versus iron, scandium, and titanium in soil litter from the four sampled soil areas and in attic dust from the trailer park displayed no distinct patterns (Figures 4-1a to 4-1c), although the plot of lead versus scandium in the roadside soil suggested a relatively minor negative correlation,  $r = -0.49$ . A slight negative correlation between lead and scandium in roadside soil suggested lead and scandium did not originate from the same source and was consistent with anthropogenic lead bearing particles displacing naturally occurring scandium bearing particles in the soil. Moreover, the lack of distinct patterns in Figures 4-1a to 4-1c was consistent with lead having been derived from a different source than the iron, scandium, and titanium in each sample set.

Further regression analysis of iron, scandium, and titanium with each other in each of the four sampled soil areas and in all four areas as a whole indicated generally strong correlations existed between these elements, although correlations were weaker in roadside soils (Table 4-2a) (Figures 4-2a to 4-2c). Additionally, relative standard deviations of iron, scandium, and titanium in each of the four sampled soil areas and between all four areas were not much greater than typical analytical error, ranging from 20 to 40% (Table 4-2b). Finally, concentrations of iron, scandium, and titanium



in soil litter from each of the four soil areas compared well with concentrations in "A," "B," and "C" soil horizons in northern Georgia (Table 4-2c) (USGS, 1975). Soil litter is part of the "A" soil horizon. The generally strong correlation of iron, scandium, and titanium with each other combined with their relatively consistent concentrations and good comparisons with regional soil concentrations indicated these elements were primarily soil components.

In contrast, not only was there very weak to no correlation of lead with the soil components, iron, scandium, and titanium, but relative standard deviations of lead in each of the four sampled soil areas were much greater than typical analytical error, ranging from 63 to 133% (Table 3-2). Furthermore, average concentrations of lead in each of the four sampled soil areas did not compare well with mean concentrations in "A," "B," and "C" soil horizons in northern Georgia (Table 4-2c), where the mean lead concentration was 21 mg/kg and the high lead concentration was 70 mg/kg in the "A" soil horizon (USGS, 1975). Soil litter is part of the "A" soil horizon. The lack of significant correlation of lead with soil components, iron, scandium, and titanium combined with the greater distribution of lead concentrations and very poor comparisons with regional soil concentrations suggested an anthropogenic source for lead. Additionally, results showing that concentrations of iron, scandium, and titanium were much more consistent in the soil than lead, suggested these elements were useful as reference markers in identifying lead contamination.

Using iron, scandium, and titanium as reference markers, scatter plots of lead versus the ratios of lead to iron, lead to scandium, and lead to titanium showed distinct linear patterns for all sample sets (Figures 4-3a to 4-3c). These linear patterns are confirmed by the results of regression analysis showing statistically significant relationships at the 99.9% confidence level (Table 4-2d). Linear patterns resulted because of the large distribution of both lead concentrations and lead to soil element ratios. Naturally occurring lead would likely have a relatively constant concentration, a relatively constant ratio with naturally occurring elements, and would display a scattered pattern. Such a scattered pattern is displayed in Figure 4-3d where the concentration of scandium versus the ratio of scandium to iron is plotted for the four soil areas and trailer park attic dust. Thus, the greater the amount of naturally occurring lead in a sample set, the greater would be the scatter of data. Since each sample set displayed a linear trend with little scatter in Figures 4-3a to 4-3c, most of the lead in the trailer park attic dust and in the soil litter from the trailer park, Exide facility, wooded areas, and roadside was probably not naturally occurring. Therefore, considering the combination of high levels of lead in the soil in the trailer park, the high levels of lead in the attic dust, the decreasing trend of lead concentrations with depth in the soil in the trailer park, and the comparisons of lead with naturally occurring elements, most of the lead found in these sample sets must have originated from anthropogenic contamination. Finally, results of similar regression analysis on the underlying "upper" and "lower" mineral soil in the trailer park (Table 4-2e) along with high lead concentrations

in the mineral soil also indicated that most of the lead in the underlying mineral soil originated from anthropogenic contamination.

#### **4.2. Airborne Transport and Deposition of Lead Contamination**

The size of lead bearing particles found in soil litter and attic dust from the trailer park, in Exide soil litter, and in wooded area soil litter were considered to determine if lead contamination in the trailer park may have occurred through airborne transport and deposition. Particle size data from individual particle analysis are reported in Appendix C, summarized in Table 3-10, and plotted as histograms in Figure 4-4. In addition, the presence of lead bearing particles in Exide air filters, the lead concentrations in trailer park attic dust, and the relative lead concentrations in trailer park soil litter and underlying mineral soil layers were considered for the same purpose.

Nearly all (96.5%) of the lead bearing particles found by individual particle analysis in trailer park soil litter were 10 micrometers in size or less (Figure 4-4). Less than 3.5% of the lead bearing particles found in the trailer park soil litter were larger than 10 micrometers, and less than 1% were much larger than approximately 20 micrometers. Particles smaller than 20 micrometers are commonly and relatively easily transported by the wind (Pye, 1987). Even the largest lead bearing particle at 220 micrometers in size was small enough to have undergone airborne transport. Furthermore, these almost exclusively small sized lead bearing particles were found over a widespread area in the trailer park, approximately 0.9 hectare (2.2 acres), consistent with airborne transport. This uniformly small size of lead bearing particles over a widespread area in trailer park soil litter suggested much of the lead had undergone airborne transport and deposition.

Dust found in the attics of houses may be expected to contain historical airborne contamination because attics are typically undisturbed over the life of the house. Access to the attic of the house in the Westgate Trailer Park was limited to screened louvers in the east and west gables, screened vents under the eaves, and a ceiling crawl space opening in the center hallway closet. Because dust in the attic probably was not present when the attic was built and access to the attic probably had not been changed, then only airborne transport could have deposited lead bearing particles in the attic dust. Furthermore, nearly all lead bearing particles analyzed in the attic dust were less than approximately 10 micrometers (93.3%) and all were less than 50 micrometers. This uniformly small size distribution of attic dust particles was consistent with airborne transport being the most probable process by which lead bearing particles could have been deposited in the attic dust. This evidence of airborne transport and deposition of trailer park attic dust in combination with

the very high concentrations of lead found in the attic dust indicated much of the lead contamination in the trailer park soil probably also occurred via airborne transport and deposition.

Further evidence of airborne transport of lead bearing particles at the trailer park was the enrichment of the soil litter in the trailer park with lead relative to the underlying mineral soil, as described above. Hogan and Wotton (1984) using a similar approach found enrichment of lead in the soil litter of a receptor area, concluding contamination occurred by airborne deposition of lead bearing particles from a nearby smelter.

As indicated above, the transport of lead contamination into the trailer park by surface or near surface groundwater flow via particle transport or the precipitation of dissolved lead species was not indicated. Widespread surface or near surface groundwater flow through the trailer park was unlikely due to the up-gradient location of the trailer park with respect to adjacent property. As indicated earlier, there was a slight upwards gradient from the Exide facility to the trailer park and a steep gradient from the railroad up to the trailer park. Also, the presence of lead bearing particles containing antimony and/or tin in the trailer park soil were not likely to have been precipitated by dissolved lead species in aqueous solution.

Evidence of airborne transport of lead bearing particles next to the trailer park at the Exide facility was found in the air filters from the high volume air sampler on the Exide side of the fence separating the trailer park and Exide properties. Airborne particulate collected by the high volume air sampler represented airborne contamination present during the sample collection period. Lead bearing particles found in these air filters indicated the presence of airborne lead particles in this area between December 1994 to September 1995. Noting that the airborne particulate collected by the high volume air sampler was limited to particles less than 10 micrometers in size, the median lead bearing particle size on the Exide air filters was 3.0 micrometers compared to 2.1 micrometers for those in the trailer park (Table 3-10). The presence of lead bearing particles in the Exide air filters supported the finding that lead in the trailer park soil had undergone airborne transport and deposition and suggested the same occurred at the Exide facility and in the adjacent wooded areas. Furthermore, as in the trailer park, nearly all of the lead bearing particles analyzed in the soil litter at the Exide facility (91.7%) as well as in the adjacent wooded areas (94.6%) were less than approximately 10 micrometers in size and all were less than 50 micrometers (Figure 4-4).

Additional results further indicated airborne transport and deposition of lead bearing particles in the wooded area soil. Daniel (1989) indicated soil in the King Acres Subdivision became contaminated by lead due to surface water runoff and concluded there was potential for exposure to contaminated soil, both at the Exide facility and in the King Acres Subdivision. The present study

confirmed soil litter in both locations contained high concentrations of lead. However, results reported here also indicated most of the lead contamination in the wooded areas that included several vacant lots in the King Acres Subdivision occurred via airborne transport and deposition. This finding was supported by the following: (1) the presence in wooded area soil litter of large amounts of lead bearing particles containing antimony and/or tin was not consistent with the transport of lead as a dissolved species, (2) the widespread distribution of lead contamination in the King Acres wooded area along with the widespread distribution of lead contamination in the wooded area along the railroad was not consistent with surface water or groundwater transport, (3) the uniformly small particle size range and wide areal distribution of lead bearing particles in the soil litter of the wooded areas, as well as the trailer park and Exide facility, was consistent with airborne transport, (4) the presence of lead bearing particles in air filters collected at the Exide facility and in trailer park attic dust demonstrated the occurrence of airborne transport of lead bearing particles around the Exide facility, and (5) enrichment of lead in the overlying soil litter in the trailer park, as described above, was also consistent with airborne transport and deposition of lead bearing particles in the nearby wooded areas due to the relative proximity of the wooded areas to the trailer park.

Considering all of the evidence presented above, including the paucity of lead bearing particles too large to be transported by common wind velocities, most, if not all, of the lead contamination in the soil of the trailer park, Exide facility, and wooded areas underwent airborne transport and deposition. Therefore, only those sources of lead which could contribute lead primarily via airborne transport were likely sources of lead in these areas. Furthermore, the combined area of the trailer park, Exide property, and wooded areas over which the almost exclusively small sized lead bearing particles were found was approximately 8 hectares (20 acres). The occurrence of such a uniformly small particle size distribution over such a widespread area, much of which was away from main roadways, suggested most of the lead in the soil of these areas was the result of airborne dispersion from an industrial source.

Finally, similar to the other areas, nearly all lead bearing particles found in roadside soil litter (93.7%) were less than approximately 10 micrometers in size and all were less than 12 micrometers (Figure 4-4). In addition, these exclusively small sized lead bearing particles were found along both sides of approximately 135 meters of roadway. This uniformly small particle size range and wide areal distribution suggested much of the lead in the roadside soil litter had undergone airborne transport and deposition as well.

### 4.3. Source Identification of Lead Contamination

Source identification of lead contamination in the Westgate Trailer Park soil and in the other soils considered in this study involved the examination of bulk elemental concentrations, lead isotope ratios, and individual particle analysis for source and receptor. Lead concentration trends in and between the four soil areas along with prevailing wind direction data were considered for indications of the source(s) of the lead contamination in these soils. Statistical correlations calculated between lead and other bulk element concentrations were useful in identifying the presence of any concomitant constituents which might act as a source signature. Lead isotope ratios were an independent set of data considered to discern sources or potential sources of lead. Finally, individual particle analysis was particularly useful as an independent means to discern sources or potential sources of lead.

#### 4.3.1. Concentration Trends

Concentration trends may indicate sources of lead contamination in soils because lead and constituents correlated with lead have higher concentrations closer to their source and lower concentrations further away. For example, Hogan and Wotton (1984) found a negative correlation of metal concentration with distance from a smelter source in their study of metal contamination in soils. Thus, if a given receptor soil contains a higher concentration of lead contamination than a soil near a particular source, then one or more other sources of lead contamination probably impacted that receptor soil. In this study, lead concentration trends were considered as an indicator of lead sources in receptor soils by comparing lead concentrations in soil from the trailer park, Exide facility, wooded areas, and roadside. Concentration trends of lead were examined by comparing average and median lead concentrations and lead distributions in the soil litter from these areas. Concentration trends within and between areas were compared to distances to potential lead sources. In addition, because antimony and tin were found to correlate with lead in Exide soil litter, as described in detail later on, concentration averages, medians, and distributions of antimony and tin in soil litter from these areas were also compared.

The distribution of lead concentrations in soil litter from the trailer park, Exide facility, wooded areas, and roadside are depicted in Figures 4-1a to 4-1c. These plots clearly distinguished lead concentrations in roadside soil litter from lead concentrations in soil litter of the Exide facility, trailer park, and wooded areas. Furthermore, lead concentrations in Exide soil litter were visually distinguishable from lead concentrations in soil litter of the trailer park and wooded areas. In

contrast, lead concentrations in soil litter of the trailer park and wooded areas were not distinguishable from each other.

An inspection of the average lead concentration in the soil litter of the roadside (167 mg/kg) and the average lead concentrations in the soil litter of the trailer park and wooded areas indicated lead concentrations in the roadside soil litter were considerably less on average, approximately 5 to 6 times less (Table 3-2 and Figure 4-5). Similarly, the average lead concentration of the Exide soil litter (16,100 mg/kg) was considerably greater than the average lead concentrations in the soil litter of the trailer park (812 mg/kg) and wooded areas (952 mg/kg), approximately 17 to 20 times greater.

As was found for lead above, plots depicting the distribution of antimony and tin concentrations (Figures 4-6 and 4-7) clearly distinguished antimony and tin in roadside soil litter from antimony and tin in soil litter of the Exide facility, trailer park, and wooded areas. Also similar to the distribution of lead, antimony, and tin concentrations in Exide soil litter were visually distinguishable from antimony and tin in soil litter in the trailer park and wooded areas. Similarly, antimony and tin concentrations in soil litter of the trailer park and wooded areas were not distinguishable from each other. Inspection of Table 3-2 and Figure 4-5 revealed average antimony and tin concentrations generally varied with average lead concentrations in the four soil areas. For example, the average antimony concentration in roadside soil litter was approximately 6 to 9 times less than that in trailer park and wooded area soil litter. Also, the average antimony concentration in Exide soil litter was approximately 14 to 22 times greater than that in trailer park and wooded area soil litter. These variations were very similar to that described for lead above.

Median concentrations of antimony, lead, and tin in the soil litter of the trailer park, Exide facility, wooded areas, and roadside are given in Table 3-2. Results of statistical testing comparing concentration medians of antimony, lead, and tin in soil litter from these four areas are given as P-values in Table 4-3. Concentration medians between two areas were compared by the Mann-Whitney statistical test, described in more detail above in the Methods section. P-values less than 0.05 indicated a statistically significant difference at the 95% confidence level between the medians of the two areas compared. P-values greater than or equal to 0.05 indicated no statistically significant difference between the medians of the two areas at the 95% confidence level. Results of these tests showed statistically significant ( $P < 0.05$ ) differences in median concentrations of antimony, lead, and tin in the soil litter between all areas except between the trailer park and wooded areas. These results agreed with observations of the data described above.

Figures 3-1, 3-2a, 3-3, 3-4, and 3-5 depict the areal distribution of lead concentrations in the soil of the trailer park, Exide facility, wooded areas, and roadside. These figures also show, along

with Figure 1-1, distances between receptor soil areas and potential lead sources such as the Exide facility and automobile exhaust from roadways. As indicated above, the average lead concentration in trailer park soil litter was considerably greater than that along the roadside. If most of the lead in the trailer park originated from automobile exhaust, then a much greater traffic volume must have existed near the trailer park than along the roadside soil sampling site to account for the greater mean lead concentration in the trailer park (Figure 1-1). Thus, the volume of automobile traffic on Old Buncombe Road and Old Chick Springs Road adjacent to the trailer park historically would have been approximately 5 times greater than that along Route 101 adjacent to the roadside soil sampling site, 2.4 kilometers (1.5 miles) north of the trailer park. Furthermore, soil lead concentrations along roadways due to automobile exhaust decrease with distance from roadways, and most lead from automobile exhaust is deposited within 30 meters (100 feet) of roadsides (Motto et al , 1970). In fact, roadside soil cores were collected much closer to the roadway, within approximately 3 meters (10 feet), than trailer park soil cores, approximately 4 to 130 meters away (13 to 430 feet) (Figures 2-2 and 2-6). Therefore, the traffic volume next to the trailer park would have to have been much greater than 5 times that along Route 101 at the roadside soil sampling site. However, Old Chick Springs Road was not a major thoroughfare like the Old Buncombe Road / Route 101 traffic artery, and an increase in automobile traffic of greater than 5 times between the roadside soil sampling site and the trailer park appeared unlikely since the roadway in both locations consisted of only two lanes. In addition, the majority of trailer park soil cores were collected further than 30 meters (100 feet) from any major roadway where considerably less impact from automobile exhaust was expected.

Similarly, little impact from automobile exhaust was expected in wooded area soil cores because they were collected approximately 100 to over 200 meters away (330 to 660 feet) from any major roadway (Figures 1-2, 2-4, and 2-5). Thus, if much of the lead in the trailer park originated from automobile exhaust, then soil litter in the trailer park would have a much greater average or median lead concentration than soil litter in the wooded areas. However, as noted above, the median lead concentrations in the soil litter in the trailer park and wooded areas were statistically indistinguishable. Therefore, because of their greater distances from traffic in combination with much greater average lead concentrations compared to roadside soil, most of the lead in the trailer park and wooded areas probably originated from a source not typically associated with roadways.

For the same reasons, little impact from automobile exhaust would have been expected in Exide soil cores because they were collected on the east side of the main Exide building outside the old grid casting area some distance away (approximately 50 meters or 160 feet) from any significant automobile traffic (Figure 1-2 and 2-3). Moreover, lead concentrations in the soil litter at the Exide

facility far exceeded concentrations which could be reasonably considered to originate from automobile exhaust, up to 6.7 weight percent.

Additional observations indicated the trailer park and wooded areas were similarly close to the Exide facility. Soil cores from the trailer park and wooded areas were collected within approximately 50 to 200 meters (160 to 660 feet) of the main Exide building. Although the trailer park and the wooded areas were primarily on opposite sides of the Exide property, they had similar average and median lead concentrations. Furthermore, as noted above, not only was the median lead concentration in the soil litter at the Exide facility distinguishable from those in the trailer park and wooded areas, but the average lead concentration in Exide soil litter was considerably greater, approximately 17 to 20 times greater. In fact, lead concentrations in soil litter from individual Exide soil cores ranged as high as 6.7 weight percent, and lead concentrations in debris from the ground immediately outside the main Exide building ranged as high as 42 weight percent. Because of the locations of the trailer park and wooded areas with their similar lead concentrations and because higher concentrations of contamination generally occur closer to the source, the considerably greater soil lead concentrations at the Exide facility suggested much of the lead in the trailer park and wooded areas originated from the adjacent Exide facility.

Profit (1990) indicated that soil at the Exide facility with lead concentrations greater than about 2,000 mg/kg were removed in 1989. Much greater concentrations of lead were found in soil at the Exide facility than 2,000 mg/kg, suggesting either much lead contamination in the soil at the Exide facility was not removed during the earlier work or much lead contamination had re-occurred outside the old grid casting area of the main building at Exide between 1989 and 1997.

Finally, the generally greater lead concentrations in soil litter on the west side of the trailer park (Figure 3-1) suggested the source of lead contamination in the trailer park soil lay to the west. Also, the presence of lead concentrations in the trailer park attic dust on the west side of the attic, approximately 4 to 6 times higher than on the east side of the attic, suggested the source of the lead contamination in the attic was to the west of the house. These lead distribution patterns were consistent with the Exide facility to the west of the trailer park being the primary source of the lead contamination in the trailer park.

#### **4.3.2. Prevailing Wind Directions**

Results presented above indicated airborne transport and deposition of lead bearing particles occurred in the trailer park soil and that a major source of the lead in the trailer park soil and the soil



of the wooded areas originated from the Exide facility. Prevailing wind directions in Greer were consistent with these results, where prevailing wind directions were almost evenly divided between northeast in the fall and winter and southwest in the spring and summer (NOAA, 1999). With the Westgate Trailer Park being located northeast of the Exide facility and the wooded area in the King Acres Subdivision being located southwest of the Exide facility (Figure 1-2), both areas were down wind of the Exide facility for long periods each year. Therefore, the combination of the prevailing wind directions, the evidence of airborne deposition, the proximity of these areas to the Exide facility, and the soil lead distribution patterns indicated lead in the soil in the trailer park and the wooded area in King Acres was primarily the result of particle fallout from the Exide facility. Modeling results of air dispersion of lead particles from the Exide facility were consistent with these findings (Chalmers, 1995).

These findings directly contradicted those of Webb (1997). Webb (1997) indicated air emissions from the Exide facility had not contributed to the lead contamination in the soil of the Westgate Trailer Park because recent air monitoring at the facility had not detected high lead emissions. Such a finding is erroneous in any case because a negative result from "recent" air monitoring cannot demonstrate historical events did not occur.

#### **4.3.3. Elemental Correlations with Lead**

Linear regressions calculated between lead and other bulk element concentrations in soil revealed the degree to which elements present in the soil were correlated with lead. Correlations of lead with naturally occurring elements were relatively weak, as described previously. Elements with a strong correlation with lead in soil containing abundant source material provided an elemental signature of that source material. Because of the high concentrations of lead in Exide soil cores collected adjacent to the main building of the facility, Exide soil litter was scrutinized for the possible abundance of lead originating from Exide facility operations. Similarly, due to the proximity to the roadway of the roadside soil cores, the roadside soil litter was scrutinized for the possible abundance of lead originating from automobile exhaust. Scatter plots of lead versus antimony, tin, and ratios of lead to antimony were constructed to further evaluate relationships between the concentrations of these elements in soil litter from the Exide facility, roadside, trailer park, and wooded areas. A comparison of these relationships between soil areas was useful in distinguishing sources of lead in receptor soils. Finally, references below to some elemental constituents expected in certain sources of lead or lead bearing materials were described in more detail in the Introduction section above.

#### 4.3.3.1. Correlations with Lead in Soil Litter at the Exide Facility

Correlation results between lead and other bulk element concentrations in the soil litter at the Exide facility are reported in Table 4-1. As indicated earlier, weak correlations of lead in Exide soil litter with such naturally occurring elements as iron, scandium, and titanium indicated most of the lead in Exide soil was not naturally occurring. A weak correlation between lead and zinc did not support primary lead smelting or coal fired power plants as significant sources of lead at the Exide facility. Moreover, there were no known primary lead smelters, coal fired power plants (DOE, 1998), or iron and steel mills in Spartenburg or Greenville counties

Furthermore, weak correlations of lead with barium, phosphorus, titanium, and zinc suggested paint was not a significant source of lead in Exide soil. In support of this finding, no obvious peeling paint was observed at the Exide facility, no paint chips were observed on the ground, and nearly all lead bearing particles found in the Exide soil were less than 10 micrometers in size. A paint source for lead would be expected to contribute a significant amount of particles, i.e., paint chips, much larger than 10 micrometers. Moreover, the particle size distribution and areal distribution of lead bearing particles found in Exide soil were consistent with widespread airborne transport indicative of an industrial source and were not consistent with paint as a major source of lead in Exide soil.

In contrast, Exide soil litter exhibited a strong correlation between lead and antimony ( $r^2 = 0.98$ ) and between lead and tin ( $r^2 = 0.94$ ). These results were independently confirmed by individual particle analysis where an abundance of lead bearing particles containing antimony and tin were found in soil litter at the Exide facility. Figures 4-6 and 4-7 show the linear trends of lead and antimony and lead and tin, respectively, in the soil litter at the Exide facility. These correlations were inconsistent with the previously mentioned sources, including automobile exhaust as well as pesticides, being major contributors to the lead contamination in Exide soil. However, these correlations were consistent with automobile battery manufacturing being the major source of lead in the Exide soil litter. In addition, these correlations were consistent with the high levels of antimony and tin found in dust from the Exide grid plate casting area. The ratio of the average lead concentration to the average antimony concentration in the Exide soil litter of 153 was consistent with the range of lead to antimony weight ratios typically used in automobile battery lead of 33 to 100 (Prengaman, 1998). As indicated previously, most of the lead in the soil litter at the Exide facility has undergone airborne transport and deposition. Airborne transport of such large amounts of lead required a nearby industrial source and eliminated any sources of lead-antimony-tin alloy material unlikely to have undergone airborne transport. No potential industrial source of lead-antimony-tin alloy was identified in the area other than the Exide facility. Furthermore, the

proximity of Exide soil core collection adjacent to the main building of the battery facility, within 15 meters (49 feet), and the Exide soil litter having the highest soil lead concentrations measured in the area showed Exide automobile battery manufacturing to be the source of the lead in the soil litter there. In addition, the moderately strong correlation of lead with sulfur in the Exide soil litter ( $r^2 = 0.69$ ) in combination with the correlations of lead with antimony and tin was also consistent with automobile battery manufacturing being the major source of lead in the Exide soil litter. Consistent with this finding, high levels of sulfur were found in Exide baghouse dust, grid casting area dust, and pasting area material.

In addition to antimony, tin, and sulfur, copper also had a strong correlation to lead in Exide soil litter with an  $r^2$  value of 0.92. The strong correlation of lead and copper in Exide soil litter was independently confirmed by the presence of trace amounts of copper in abundant lead rich particles in Exide soil litter, as determined by individual particle analysis. Abundant lead rich particles with trace amounts of copper were also found in Exide process materials and dust. This, along with high levels of copper in bulk samples of dust from the Exide grid plate casting area, further linked lead in Exide soil litter to lead from Exide manufacturing.

Although statistically significant at only the 95% confidence level, lead and bromine in the Exide soil had a moderately strong relationship ( $r^2 = 0.46$ ). Shown in Figure 4-8, this relationship was consistent with the high levels of bromine found in Exide process materials and dust, such as baghouse dust, grid plate casting area dust, and ground debris material. Automobile exhaust was not a significant source of the lead and bromine in the soil litter at the Exide facility due to the extremely high concentrations of lead in the Exide soil and the distances from Exide soil core locations to nearby roadways

If a relatively strong correlation between lead and a given element was not apparent in soil adjacent to a potential source, then a strong correlation would not be expected in more distant receptor soils. In more distant receptor soils, the concentration of a given element due to source material would be much less relative to background soil contributions of that element. Thus, any correlation with lead for a given element would be expected to be weaker in more distant receptor soil than adjacent to the source. Based on analyses of the Exide soil cores collected, the weak or negligible correlations of lead with barium, calcium, silicon, and sodium did not provide useful signature elements for distinguishing lead originating from the Exide facility in receptor soil. This was despite these elements having been associated with automobile battery manufacturing and having been detected in relatively high quantities in Exide process materials and dust. For example, barium was abundant in samples from the Exide pasting area and calcium, silicon, and sodium were abundant in samples from the Exide grid plate casting area. Other elements which did not provide

useful signatures for lead from the Exide facility based on the data collected included iron, scandium, and titanium, as noted previously. Also included were aluminum, beryllium, boron, cobalt, lanthanum, lithium, magnesium, manganese, phosphorus, strontium, vanadium, yttrium, and zinc. Again, this was despite some of these elements having been detected in relatively high quantities in Exide process materials and dust. For example, aluminum, phosphorus, and zinc were abundant in samples from the Exide grid plate casting area.

#### 4.3.3.2. Correlations with Lead in Soil Litter along the Roadside

Correlation results between lead and other bulk element concentrations in roadside soil litter are reported in Tables 4-1. As indicated earlier, weak correlations of lead in roadside soil litter with such naturally occurring elements as iron, scandium, and titanium indicated most of the lead in roadside soil was not naturally occurring. The correlation of lead and antimony and the correlation of lead and tin for roadside soil litter was negligible ( $r^2 = 0.03$  and  $r^2 = 0.002$ , respectively), suggesting little of the lead in the roadside soil litter may have originated from automobile battery manufacturing. Figures 4-6 and 4-7 show the lack of a linear relationship between lead and antimony and lead and tin. In addition, the correlation of lead concentrations with the concentration ratios of lead to antimony in roadside soil litter was statistically significant at the 99.9% confidence level,  $r^2 = 0.68$  (Table 4-2d and Figure 4-9). This correlation result and data scatter plot indicated an abundance of anthropogenic lead contamination in roadside soil litter which was relatively independent of antimony concentration, suggesting a different source of lead in roadside soil than that found in Exide soil. These results suggested the roadside area chosen was distant enough from the Westgate Trailer Park and Exide facility to have been minimally impacted by air particulate emissions from the Exide facility.

Furthermore, relatively weak correlations of lead with barium and titanium suggested paint was not a major source of lead in roadside soil. Although yellow centerline road paint was present on the road at the roadside soil sampling site, abundant paint chips were not observed on the ground nearby and nearly all lead bearing particles found in the roadside soil were less than 10 micrometers in size. A paint source for much of the lead would be expected to contribute an abundance of particles in the form of paint chips much larger than 10 micrometers. In addition, the particle size distribution and areal distribution of lead bearing particles found in roadside soil were consistent with widespread airborne transport and were not consistent with paint as a major source of lead.

Indicating an automobile source of lead in roadside soil was the relationship between lead and bromine (Figure 4-8). Lead and bromine showed a moderately strong correlation in roadside

soil ( $r^2 = 0.41$ ), consistent with a significant amount of the lead in roadside soil originating from automobile exhaust. Moreover, statistically significant correlations at the 99.9% confidence level were also found in the roadside soil litter between lead, phosphorus, and sulfur. These relationships were relatively weak, as indicated by the relatively low  $r^2$  values of 0.18 and 0.28 for lead with phosphorus and sulfur, respectively. The combined relationships of lead with bromine, phosphorus, and sulfur were indicative of automobile exhaust as an important source of lead in the roadside soils. However, lead was also expected to be associated with phosphorus in soil adjacent to roadways due to weathering (authigenic) reactions between automobile exhaust particles and the phosphorus present in soil (Nriagu, 1984). Although lead and bromine in automobile exhaust particles had a weight concentration ratio of approximately 2.6, approximately 75% of the bromine was lost to the atmosphere within minutes after particle formation (Robbins and Snitz (1972). This accounted for lead to bromine ratios as high as 11 in atmospheric particles (Eldred et al., 1978), which was consistent with the ratio of the average lead concentration to the average bromine concentration in the roadside soil litter of 14.

Although a moderately strong correlation between lead and zinc ( $r^2 = 0.66$ ) in roadside soil was consistent with primary lead smelting, coal fired power plants, and paint as significant sources of lead, there were no known primary lead smelters or coal fired power plants (DOE, 1998) in Spartanburg or Greenville counties and a significant paint source was unlikely, as described above. Furthermore, the abundance of brake dust particles containing copper, lead, and zinc found in roadside soil by individual particle analysis and described in detail below was not a satisfactory explanation for the lead-zinc relationship found in the bulk samples. First, the concentration of lead in these brake dust particles appeared to be relatively minor. Second, there was a lack of correlation between lead and copper in roadside soil. The most probable sources of zinc associated with lead in the roadside soil were from automobiles. These included particles from the combustion of motor oil and the wear of tires (Pierson and Brachaczek, 1975 and 1983; Fukuzaki et al., 1986; Fergusson and Kim, 1991; Rogak and Pott, 1997). The combustion of motor oil was also a source of phosphorous. Particles of motor oil combustion and tire wear as an explanation for the lead-zinc relationship found in the bulk roadside soil implied a correlation between the amount of automobile exhaust lead produced and the amount of oil combusted and/or tire wear incurred by automobiles. Finally, the airborne transport and deposition that was determined previously for lead in roadside soil litter was consistent with lead from automobile exhaust and zinc from oil combustion.

Although statistically significant correlations occurred for lead with aluminum and scandium in the roadside soil at the 99.9% confidence level, these relationships were negative and relatively weak, as indicated by the relatively low  $r^2$  values of 0.32 and 0.24, respectively. Negative correlations for lead with aluminum and scandium ( $r = -0.56$  and  $r = -0.49$ ) suggested lead did not

originate from the same source as scandium and aluminum. Negative correlations were consistent with anthropogenic lead bearing particles displacing naturally occurring aluminum and scandium bearing particles in the soil.

#### **4.3.3.3. Correlations with Lead in Soil Litter in the Trailer Park**

Correlation results between lead and other bulk element concentrations in the soil litter in the trailer park are reported in Table 4-1. As indicated earlier, weak correlations of lead in trailer park soil with such naturally occurring elements as iron, scandium, and titanium indicated most of the lead in trailer park soil was not naturally occurring. Weak to negligible correlation of lead with barium, phosphorus, sulfur, titanium, and zinc suggested paint was not a significant source of lead in the trailer park soil. In support of this finding, PVC siding was found on the house in the trailer park and aluminum siding was found on most, if not all, trailers in the park. Additionally, no obvious peeling paint was observed in the trailer park, no paint chips were observed on the ground, the abundant lead in the trailer park attic dust had no probable paint source, and nearly all lead bearing particles found in the soil were less than 10 micrometers in size. A paint source of lead would be expected to contribute an abundance of lead bearing particles much larger than 10 micrometers. Moreover, the size and areal distribution of lead bearing particles in the trailer park, as described previously, were not consistent with paint as a major source of lead in the trailer park soil.

The lack of correlation of lead with arsenic, copper, and zinc in trailer park soil was not consistent with primary lead smelting or coal fired power plants being significant sources of lead in the trailer park. As noted previously, there were no known primary lead smelters or coal fired power plants in Spartenburg or Greenville counties. Due to relatively high arsenic levels relative to lead in lead bearing pesticides, the lack of correlation between lead and arsenic in trailer park soil suggested pesticides were not significant sources of lead in the trailer park. In addition to the lack of correlation between lead and arsenic, the lack of lead bearing particles in the trailer park soil greater than 10 micrometers indicated lead shot was also not a significant source of lead in the trailer park. Furthermore, the size and areal distribution of lead bearing particles in the trailer park soil, as described previously, were not consistent with lead shot as a major source of lead in the trailer park. Although arsenic has been associated with automobile battery lead, the relatively low arsenic concentrations found in the Exide soil suggested arsenic levels in lead from the Exide facility were too low to provide an observable signature in receptor soils.

In contrast to the preceding lead relationships, the correlation of lead and antimony in trailer park soil litter was strong ( $r^2 = 0.88$ ). Figure 4-6 shows the linear trend for lead and antimony in the trailer park soil litter. This correlation was consistent with lead concentrations which were relatively independent of lead to antimony concentration ratios in Figure 4-9, where  $r^2 = 0.10$  (Table 4-2d). The appearance of this plot differs from that in Figures 4-3a to 4-3c due to the trailer park containing abundant lead contamination with relatively consistent lead to antimony concentration ratios. This result was independently confirmed by individual particle analysis which found an abundance of lead rich particles containing antimony in soil litter of the trailer park. The strong correlation of lead and antimony was inconsistent with such sources as those mentioned above, including automobile exhaust. However, the strong correlation of lead and antimony in trailer park soil litter was consistent with the lead-antimony alloy used in automobile battery manufacturing. In fact, the ratio of the average lead concentration to the average antimony concentration in the trailer park and Exide soils of 172 and 153, respectively, were consistent with each other and were consistent with the range of lead to antimony weight ratios typically used in automobile battery lead of 33 to 100 (Prengaman, 1998). Furthermore, the strong correlation of lead and antimony in trailer park soil litter was also consistent with the even stronger correlation of lead and antimony in the Exide soil ( $r^2 = 0.98$ ). The elemental relationships found with lead close to its source were expected to weaken in more distant receptor soil. Finally, the areal extent of the trailer park soil exhibiting a strong lead-antimony relationship was great enough to suggest the major source of the lead was an industrial source. The Exide battery facility adjacent to the trailer park was the only industrial source of lead-antimony alloy known in the area.

The relationship of lead and tin concentrations in trailer park soil litter are shown in Figure 4-7. Although bulk analysis of soil litter in the trailer park showed a relatively weak correlation of lead and tin ( $r^2 = 0.05$ ), individual particle analysis demonstrated the common occurrence of tin, typically with antimony, in lead bearing particles in trailer park soil litter. The relationship between lead and tin concentrations in much of the trailer park soil appeared very similar to that in much of the wooded area soil. This similarity, along with a moderately strong correlation of lead and tin ( $r^2 = 0.52$ ) in wooded area soil and the abundance of lead and tin bearing particles in trailer park soil, suggested much of the lead and tin in trailer park soil was from the same source. The most likely source for the lead and tin in trailer park soil litter was the Exide facility for many of the same reasons, as described above for the lead and antimony in trailer park soil. The weak correlation of lead and tin in bulk analysis of trailer park soil litter may have been due to possible contributions of anthropogenic tin in a relatively small number of soil cores from an unknown source. Figure 4-7 shows several relatively high tin concentrations in trailer park soil litter relative to the overall lead-tin concentration trend of the trailer park and wooded area soils.

No appreciable correlation was found in trailer park soil between lead and copper although Exide soil litter exhibited a strong relationship between lead and copper. Individual particle analysis indicated the amount of copper in lead bearing particles from the Exide facility only occurred in trace amounts, suggesting the copper signature of these particles may have been easily lost in receptor soil. A low copper contribution from lead bearing particles relative to background soil copper may have resulted in a lack of correlation of lead and copper in the trailer park soil litter. This was consistent with elemental relationships in lead source material becoming weaker in receptor soil

Lead and bromine showed a moderately strong correlation in trailer park soil ( $r^2 = 0.51$ ), consistent with the Exide facility or automobile exhaust or both as sources of the lead there (Figure 4-8). Because the correlation of lead and bromine in trailer park soil was slightly stronger than that in either the Exide or roadside soil, both the Exide facility and automobile exhaust probably contributed lead to the trailer park soil. However, the lack of correlation of lead with phosphorus, sulfur, and zinc in the trailer park soil suggested automobile exhaust was not the major contributor of the lead in the trailer park. The correlation of lead with phosphorus and sulfur in the roadside soil was consistent with automobile exhaust, while the correlation of lead with zinc was consistent with other automobile sources such as tires and motor oil. The ratio of the average lead concentration to the average bromine concentration in the trailer park soil litter was 96, considerably greater than that found in the roadside soil litter of 14. For the lead to bromine ratio in the trailer park to be nearly 7 times greater than that expected due to automobile exhaust, another source of lead other than automobile exhaust must have been responsible for most of the lead in the trailer park soil. Finally, as noted previously, automobile exhaust was not the major source of lead in trailer park soil litter due to the distance from most soil core locations to nearby main roadways.

Although Exide soil litter exhibited a moderately strong relationship between lead and sulfur, no appreciable correlation was found in trailer park soil between lead and sulfur. A low sulfur contribution from lead bearing particles relative to background sulfur occurring in the soil may have resulted in a lack of correlation of lead and sulfur in the trailer park soil litter. Again, this was consistent with elemental relationships in lead source material becoming weaker in receptor soil.

Finally, no appreciable correlation of lead with barium was found in trailer park soil, although barium has been associated with automobile battery manufacturing. However, this result was consistent with findings for the Exide soil.



#### 4.3.3.4. Correlations with Lead in Soil Litter in Wooded Areas

The wooded areas adjacent to the Exide facility and Westgate Trailer Park included several vacant lots in the King Acres Subdivision and overgrown areas along the railroad tracks, as described previously. Results from these areas were important because the trees and undergrowth in these areas indicated soil there had not been disturbed for years and, based on the size of some trees, probably not for decades. Thus, results from the wooded areas were expected to represent long term particle fallout resulting from airborne transport and deposition.

Correlation results between lead and other bulk element concentrations in the soil litter in the wooded areas are reported in Table 4-1. For the same reasons, as described above for the trailer park soil litter, naturally occurring lead, paint, primary lead smelting, and fly ash from coal fired power plants were not significant sources of lead in the soil litter of the wooded areas. No significant sources of paint were observed in the wooded areas and no paint chips were observed on the ground.

In contrast, soil litter in the wooded areas exhibited a strong correlation between lead and antimony concentrations as in the trailer park ( $r^2 = 0.94$ ). Figure 4-6 shows the linear trend for lead and antimony in the wooded area soil which coincided with the trailer park trend. This correlation was consistent with lead concentrations which were relatively independent of lead to antimony concentration ratios in Figure 4-9, where  $r^2 = 0.04$  (Table 4-2d). The appearance of this plot differs from that in Figures 4-3a to 4-3c because wooded area soil litter contained abundant lead contamination with relatively consistent lead to antimony ratios, giving a relatively horizontal trend. As in the trailer park soil litter, this result was independently confirmed by individual particle analysis which found an abundance of lead rich particles containing antimony in soil litter of the wooded areas. The strong correlation of lead and antimony was inconsistent with such sources as those mentioned above, including automobile exhaust. However, the strong correlation of lead and antimony in wooded area soil litter was consistent with the lead-antimony alloy used in automobile battery manufacturing. In fact, the ratio of the average lead concentration to the average antimony concentration in the soil litter of the wooded areas and Exide facility of 125 and 153, respectively, were consistent with each other and were consistent with the range of lead to antimony weight ratios typically used in automobile battery lead of 33 to 100 (Prengaman, 1998).

Lead and tin also showed a moderately strong correlation in wooded area soil litter ( $r^2 = 0.52$ ) (Figure 4-7). As noted previously, this correlation of lead with tin in wooded area soil litter was also independently confirmed by individual particle analysis where observations were made of an abundance of lead rich particles containing tin, typically with antimony, in wooded area soil litter.

The correlation of lead with tin was also inconsistent with such sources as those mentioned above, as well as automobile exhaust and pesticides, being major contributors to the lead in the soil litter of the wooded areas. However, the correlations of lead with tin and antimony were consistent with the lead-antimony-tin alloy used in automobile battery manufacturing and were consistent with the even stronger correlations of lead with antimony ( $r^2 = 0.98$ ) and lead with tin ( $r^2 = 0.94$ ) found in the Exide soil. The elemental relationships found with lead close to its source were expected to weaken in more distant receptor soil. Furthermore, the areal extent of the wooded area soil exhibiting strong lead-antimony and lead-tin relationships was great enough to suggest the major source of the lead was an industrial source. The Exide battery facility adjacent to the wooded areas trailer park was the only industrial source of lead-antimony-tin alloy known in the area.

Consistent with a weakening elemental-lead relationship with distance from the source was a relatively weak correlation in wooded area soil between lead and copper. The Exide soil litter exhibited a strong relationship between lead and copper. Individual particle analysis indicated the amount of copper in lead bearing particles from the Exide facility only occurred in trace amounts, suggesting the copper signature of these particles may have been easily lost in receptor soil. A low copper contribution from lead bearing particles relative to background soil copper may have resulted in a weak correlation of lead and copper in wooded area soil litter. Thus, the locations of the trailer park and wooded areas around the Exide facility along with stronger relationships of antimony, copper, and tin with lead in Exide soil relative to that in trailer park and wooded area soil suggested much of the lead in trailer park and wooded area soil originated from the adjacent Exide facility.

The moderately strong correlation of lead with sulfur in the wooded area soil litter ( $r^2 = 0.61$ ) along with the correlations of lead with antimony and tin was consistent with automobile battery manufacturing and with the lead and sulfur correlation in the Exide soil litter. The slightly weaker correlation of lead and sulfur in the wooded areas relative to that found in the Exide soil litter was consistent with a weakening elemental-lead relationship with distance from the source.

Although a positive and statistically significant correlation occurred between lead and phosphorus in wooded area soil at the 99.9% confidence level, this relationship was relatively weak, as indicated by a relatively low  $r^2$  value of 0.21. This weak relationship may have resulted from lead in Exide process material and dust, since phosphorous was found at percent levels and in an abundance of lead bearing particles in dust from Exide's old grid plate casting area. However, weathering reactions (i.e., authigenic alteration) of lead bearing particles in the soil with soil phosphate may have been common. The greater abundance of lead bearing particles containing phosphorus in soil litter compared to attic dust or air filters was consistent with the weathering of lead bearing particles with soil phosphate. Lead phosphate mineral phases have greater stability, i.e.,

lower solubilities, in surface soils than lead oxides, hydroxides, sulfates, or carbonates (Nriagu, 1984). Furthermore, the location of the wooded areas away from any significant automobile traffic, as noted previously, suggested automobile exhaust did not contribute significantly to the weak relationship between lead and phosphorus in wooded area soil.

As with phosphorous, calcium displayed a positive, though relatively weak ( $r^2 = 0.15$ ), correlation with lead in wooded area soil that was statistically significant at the 99.9% confidence level. This weak relationship may also have resulted from lead in Exide process material and dust, since calcium was found up to percent levels in dust from Exide's old grid plate casting area. However, due to the relative weakness of the relationship and the lack of correlation between lead and calcium in other areas, the cause of the relationship between lead and calcium in wooded area soil was not clear.

The relationship between lead and bromine in the soil litter of the wooded areas overall appeared relatively weak ( $r^2 = 0.09$ ). However, the correlation of lead and bromine in the wooded area soil in the King Acres Subdivision ( $r^2 = 0.27$ ) was much stronger and more statistically significant (99%) than that in the wooded area soil along the railroad ( $r^2 = 0.13$ , <90%) (Figure 4-8). This was despite bromine concentrations in the wooded area along the railroad being higher on average (8.8 mg/kg) than those in the wooded area in King Acres (6.0 mg/kg). The relationship between lead and bromine in the wooded area in King Acres was consistent with the Exide facility or automobile exhaust or both as sources of the lead there. However, the ratio of the average lead concentration (1110 mg/kg) to the average bromine concentration (6.0 mg/kg) in the wooded area soil in King Acres was 185, approximately 13 times greater than that found in the roadside soil litter of 14. Similarly, the average lead to average bromine concentration in the wooded area soil along the railroad was 55, approximately 4 times greater than that found in the roadside soil litter of 14. Because the average lead to average bromine concentration in the soil along the railroad and in King Acres and was approximately 4 to 13 times greater than that expected due to automobile exhaust, another source was clearly responsible for most of the lead in the soil in these wooded areas. Furthermore, the relationship between lead and sulfur in the King Acres wooded area soil was much stronger ( $r^2 = 0.62$  at the 99.9% confidence level) than that in the roadside soil ( $r^2 = 0.28$ ). In addition, the relationship between lead and zinc in the King Acres wooded area soil was much weaker ( $r^2 = 0.17$ ) than that in the roadside soil ( $r^2 = 0.66$ ). This difference in the relationships of lead with sulfur and zinc between the King Acres wooded area soil and the roadside soil also suggested automobile exhaust was not an important source of lead in the wooded area in the King Acres Subdivision. As noted above, the location of the wooded areas in King Acres and along the railroad were some distance away from any significant automobile traffic, approximately 100 to 300 meters (330 to 980 feet). This further suggested automobile exhaust was not a major source of lead

in the wooded areas in King Acres or along the railroad. Although some wooded area soil cores were collected adjacent to the railroad, negligible impact to this soil was expected from lead in the diesel exhaust of train locomotives. This was because trains represent a low traffic volume relative to highway vehicles and because lead levels found in diesel exhaust are low relative to gasoline exhaust (Fukuzaki et al., 1986).

As in the trailer park, no appreciable correlation of lead with barium was found in wooded area soil, although these elements have been associated with automobile battery manufacturing. However, these results were consistent with correlations of lead with barium in soil litter at the Exide facility.

A statistically significant correlation occurred between lead and silicon in the wooded area soil litter at the 99.9% confidence level. However, this relationship was relatively weak as indicated by the relatively low  $r^2$  value of 0.16. The negative correlation between lead and silicon ( $r = -0.41$ ) suggested lead did not originate from the same source as the silicon. A negative correlation was consistent with anthropogenic lead bearing particles displacing naturally occurring silicate particles in the soil.

#### 4.3.4. Comparison of Source Material and Receptor Media

Data collected from potential source material, such as Exide process materials and dust, for direct comparison with data from receptor soils and other receptor media, such as trailer park attic dust, were valuable for source identification of lead contamination in the trailer park and wooded areas. For example, dust from the old grid plate casting area at the Exide facility and debris from the ground immediately outside the main Exide building contained abundant antimony and tin. The concentration ratios of lead to antimony in dust from the grid plate casting area were 41, 43, and 131. The concentration ratios of lead to antimony in debris from the ground immediately outside the main Exide building were 64, 149, 198, 417, and 465. Most of these ratios were within 2 times the lead to antimony weight ratios typically used in automobile battery lead, a range of 33 to 100 (Prengaman, 1998). Lead to antimony concentration ratios considerably greater than 100 indicated a significant impact by lead "oxide" particles from the Exide facility in samples of Exide soil and dust, trailer park soil and attic dust, and wooded area soil. Lead "oxide" particles from the Exide facility did not contain significant antimony or tin and are described in detail in the Individual Particle Analysis section below. The concentration ratios of lead to antimony in dust from the grid plate casting area and Exide ground debris are plotted against lead concentration in Figure 4-9 for comparison to other samples. The lead to antimony ratios in most samples of Exide soil and dust, trailer park soil and

attic dust, and wooded area soil compare reasonably well. The relatively high lead to antimony ratios in a few samples of Exide soil and ground debris suggested a significant impact in those samples by lead "oxide" particles from the Exide facility.

The relationships between lead and antimony and lead and tin in Exide grid plate casting area dust and ground debris are shown in Figures 4-6 and 4-7, respectively. These data were consistent with the linear relationships between lead and antimony and lead and tin established previously for soil litter in the trailer park, Exide facility, and wooded areas. In addition, trends for lead and antimony and lead and tin in the three trailer park attic dust samples also appeared linear. The relationships of lead and antimony and lead and tin between the aforementioned receptor soils and the trailer park attic dust were clearly collinear. In fact, results for trailer park and wooded area soil litter were nearly superimposed. These collinear relationships suggested an identical source of lead contamination for the attic dust and the aforementioned receptor soils. Concentrations of antimony and tin in Exide ground debris were as high as 0.4 and 0.6 weight percent, respectively, with lead concentrations as high as 42% by weight. These concentrations were so much higher than those in trailer park, Exide, or wooded area soil, that they clearly indicated the closer proximity of the ground debris samples to the source of lead contamination found in the receptor soils. The higher lead, antimony, and tin concentrations in the Exide soil than the trailer park or wooded area soil showed Exide soil to be closer to the source of lead contamination than trailer park or wooded area soil. The similar lead, antimony, and tin concentrations in the soil litter of the trailer park and wooded areas indicated these soil areas were similar distances from the source of lead contamination. The Exide facility was located within a similar distance of both the trailer park and the wooded areas. The collinear relationship between the lead, antimony, and tin concentrations in source material and receptor soils was consistent with the dilution of Exide process materials and dust by soil, where greater dilution occurred in soil areas further from the Exide facility.

Bromine concentrations were also collected from potential source material such as the roadside soil and Exide process materials and dust for direct comparison with receptor soils and other receptor media. The ratios of average lead concentration to average bromine concentration in the trailer park soil (96) and attic dust (247), in the wooded area soil in King Acres (185), and in the wooded area soil along the railroad (55) were considerably greater than that in the roadside soil (14). In contrast, the ratio of average lead to average bromine in Exide soil (2970), and the lead to bromine ratios in Exide process materials and dust (298 to 80800), were considerably greater than those found in trailer park soil, attic dust, or wooded area soil.

Relationships between lead and bromine are shown in Figure 4-8 for trailer park, Exide facility, wooded area, and roadside soil; trailer park attic dust; and Exide baghouse dust, grid plate

casting area dust, and ground debris material. The lead-bromine trend in the Exide soil reflected the higher lead to bromine ratios described above, where the Exide soil contained extremely high lead concentrations relative to the roadside soil. In addition, the relationship of lead and bromine in Exide soil, dust, and debris appeared relatively linear. This trend along with relatively high bromine concentrations in Exide dust and debris, as high as 2490 mg/kg in baghouse dust, were consistent with the lead-bromine relationship in Exide soil having originated from the Exide facility. In contrast, the lead-bromine trend in the roadside soil reflected the lower lead to bromine ratios described above, where the roadside soil contained higher bromine concentrations on average compared to the Exide soil. Lead-bromine relationships in the trailer park and wooded area soil exhibited significant overlap and occurred between the trends in the Exide and roadside soil. This reflected the lead to bromine concentration ratios in the trailer park and wooded area soil occurring between those in roadside soil and at the Exide facility, as described above. The intermediate lead and bromine relationships in trailer park soil, attic dust, and wooded area soil were consistent with lead and bromine originating from both the Exide facility and automobile exhaust. The generally higher bromine concentrations in the trailer park soil relative to wooded area soil suggested a generally greater impact in the trailer park soil by automobile exhaust. However, lead to bromine ratios approximately 4 to 18 times greater than that expected due to automobile exhaust indicated automobile exhaust was no more than a minor source of lead in the trailer park and wooded areas.

Means by which Exide process materials and dust may have undergone airborne transport to receptor soils included venting processes or uncontrolled fugitive emissions from facility operations. For example, the garage door to the lead oxide area may have been frequently open during operations due to the great heat produced by the lead melting pots allowing fugitive dust emissions to escape. In addition, one or more outside personnel doors from the grid casting area on the east side of the main Exide building may have allowed fugitive dust emissions to escape if left opened.

As noted above, Figures 4-6 and 4-7 show the lack of a linear relationship between lead and antimony, and lead and tin in roadside soil litter. Figure 4-9 further distinguishes lead in roadside soil litter from lead in the other soils by indicating an abundance of anthropogenic lead contamination generally independent of antimony concentration. Thus, lead contamination in roadside soil originated from a different source than lead found in the other soils surrounding the Exide facility. This conclusion justified the roadside soil being considered non-receptor soil with respect to the Exide facility.

#### 4.3.5. Lead Isotope Ratios

Figures 4-10a and 4-10b display the lead isotope ratios determined, as described earlier. Figure 4-10a shows the lead isotope ratios,  $^{207}\text{Pb}/^{206}\text{Pb}$  versus  $^{204}\text{Pb}/^{206}\text{Pb}$ , and Figure 4-10b shows the lead isotope ratios,  $^{207}\text{Pb}/^{206}\text{Pb}$  versus  $^{208}\text{Pb}/^{206}\text{Pb}$ . Included are measurements of soil litter from the Westgate Trailer Park, the Exide facility, wooded areas adjacent to the Exide facility, and roadside soils. Also included are measurements of attic dust from the Westgate Trailer Park and measurements of process materials and dust from the Exide facility.

These data did not show a clear distinction between the lead isotope compositions of the different sample populations due to extensive overlap of the data sets. As a result, these lead isotope measurements of bulk samples did not provide conclusive evidence for a source of lead in trailer park soil. However, results suggested a possible gap in the sampling of Exide process materials and dust. Sample 40 was a sample of dust and debris on the ground outside the south side of the Exide facility and much further west than other similar samples collected. Because of its location close to the older part of the facility, this sample was believed to contain abundant historic lead from the Exide facility. Other similar samples were collected near newer parts of the facility on and close to the east side of the main building. Lead isotope ratios in sample 40 were much higher than in any other sample collected from Exide and were consistent with the range of lead isotope ratios found in the trailer park and wooded areas. Because bulk elemental data presented earlier links much of the lead in the trailer park and wooded areas to lead at the Exide facility, a similar range of lead isotope ratios would be expected for samples from the Exide facility, trailer park, and wooded areas. Therefore, additional sampling of dust on the southwest side of the Exide facility may likely confirm the wide range of lead isotope compositions found in Exide samples.

#### 4.3.6. Individual Particle Analysis

Results of the individual particle analysis conducted for this study are discussed below. Implications of the size, morphology, chemistry, and frequency of occurrence of the lead bearing particles studied are considered. The frequency of occurrence of lead bearing particles is given in Table 3-8 and shown in Figure 4-11.

As noted earlier, nearly all lead bearing particles analyzed in the soil litter of the trailer park, Exide facility, and wooded areas were less than approximately 10 micrometers in size (Figure 4-4). Such uniformly small particle size distributions were consistent with much of the lead in the soil

litter of these areas having undergone airborne transport and deposition. In fact, such a small particle size distribution occurring over the widespread area between the trailer park, Exide property, and wooded areas, suggested most of the lead in the soil of these areas was the result of airborne dispersion from an industrial source.

In addition, nearly all lead bearing particles analyzed in the soil litter along the roadside were less than 10 micrometers in size with a maximum of less than 12 micrometers. Again, this uniformly small particle size distribution suggested much of the lead in the soil litter along the roadside may have undergone airborne transport and deposition.

Furthermore, a great abundance of lead bearing particles in samples taken from the pasting and lead oxide areas of the Exide facility were less than 10 micrometers in size. This was consistent with the main ingredient of battery paste being a finely divided mixture of lead monoxide powder and metallic lead particles (Bullock and Pierson, 1998). In addition, it was consistent with the size distributions of lead bearing particles found in the soil litters of all areas sampled.

The morphology, or shape, of most of the lead bearing particles examined did not provide many unique characteristics for distinguishing between particle sources. In general, most particles examined were irregular in shape. To a much lesser extent, blocky, ovoid, and spherical particles were discernable in all of the sample sets. However, no clear distinctions could be made between different sample sets based on particle morphologies.

More useful particle characteristics were the elemental associations found in the lead bearing particles. Results of individual particle analysis indicated an abundance of lead rich particles containing antimony and/or tin as well as a lesser occurrence of antimony or tin rich lead bearing particles (Figure 4-11, Table 3-8, classes 1-4, 10-19). The association of lead with antimony and tin indicated anthropogenic contamination and was consistent with automobile battery manufacturing, as discussed previously. However, this association was not consistent with such sources as naturally occurring lead, automobile exhaust, pesticides, paint, primary lead smelting, iron and steel manufacturing, and fly ash from coal fired power plants. Not only were lead rich particles containing antimony and/or tin common in process materials and dust from the Exide facility, but they were abundant in the soil litter of the Exide facility, trailer park, and wooded areas. In contrast, lead rich particles containing antimony and/or tin were not found in the roadside soil litter. Since lead rich particles containing antimony and/or tin were common in process materials and dust from the Exide facility and were consistent with materials used in automobile battery manufacturing, the Exide facility was recognized as a possible source of these particles. Moreover, lead bearing particles containing antimony and/or tin were abundant in soil litter of the Exide facility, trailer park, and



wooded areas. These areas contained significantly greater soil lead concentrations and were considerably closer to the Exide facility than the roadside soil. Because greater soil lead concentrations are expected closer to the source, the Exide facility was strongly implicated as the source of lead bearing particles containing antimony and/or tin in the surrounding soil areas. Independent confirmation of these results by individual particle analysis was given by the correlations of lead with antimony and tin in results of bulk soil analysis. Although phosphorus was clearly detected in many of these lead bearing particles, the presence of phosphorus did not prove to be useful for discriminating particle origin, as described later. Results of individual particle analysis also indicated traces of copper were common in lead rich particles containing antimony and tin, especially in particle classes 10 and 16. As indicated above, lead bearing particles containing antimony and/or tin, including particle classes 10 and 16, were linked to the Exide facility. In fact, lead bearing particles containing antimony and/or tin (classes 1-4, 10-19) represented one of two important general groups of lead particle types found originating from the Exide facility.

An abundance of lead rich particles containing trace amounts of copper with no detectable antimony or tin, especially in particle classes 20 and 21 (Figure 4-11, Table 3-8), were also found. This lead particle type with a trace of copper and without detectable antimony or tin was also common in Exide process materials and dust and in soil litter of the Exide facility and trailer park. In addition, this lead particle type was predominant in trailer park attic dust. The correlation of lead and copper in bulk elemental analysis of Exide soil litter independently confirmed results of individual particle analysis detecting traces of copper in lead bearing particles. In contrast, lead bearing particles containing traces of copper were rare in the more distant roadside soil litter. Since lead rich particles containing traces of copper with no detectable antimony or tin were common in process materials and dust from the Exide facility, the Exide facility was recognized as a possible source of these particles. Furthermore, the Exide facility was indicated as the primary source of this latter type of lead particle in the Exide soil and in the adjacent trailer park for the following reasons. First, this type of lead particle was abundant in Exide soil litter, representing approximately 66% of the total lead bearing particles found there. Since the Exide soil litter also contained considerably higher lead concentrations than any of the other soil areas, greater than 16 times on average, and because higher concentrations are expected closer to the source, then a great abundance of this lead particle type must have originated from the Exide facility. Second, this lead particle type was also abundant in the attic dust (approximately 100%) and soil litter (approximately 46%) of the trailer park in contrast to the more distant roadside soil where none was found. The trailer park soil litter also contained considerably higher lead concentrations than the more distant roadside soil, almost 5 times on average. Again, since greater soil lead concentrations are expected closer to the source and since trailer park soil and attic dust also contained an abundance of this lead particle type, the Exide facility was implicated as the source. As a final note, a small number of lead rich particles

containing trace amounts of copper also contained trace amounts of zinc (classes 17-18, 22-23) and were found in process materials and dust from the Exide facility and in trailer park soil litter. This occurrence suggested trace amounts of zinc, as well as copper, in lead rich particles were also indicative of lead from the Exide facility.

Lead rich particles with no detectable antimony, copper, tin, and/or zinc were common in Exide process materials and dust and were predominant in Exide air filters, especially particle class 30 (Figure 4-11, Table 3-8). However, this lead particle type was not common in other sample sets. Since these lead rich particles were common in process materials and dust from the Exide facility and were consistent with materials used in automobile battery manufacturing, the Exide facility was recognized as a source of these particles. Considering the foregoing and the location of the high volume air sampler on the Exide property away from any main roadway, the Exide facility was implicated as the source of these particles in the air filters. Therefore, the presence of these particles on the air filters indicated lead rich particles from the Exide facility had been released into the air during the time period of the sampling. However, because these lead rich particles did not exhibit distinguishing chemical characteristics, other sources of this lead particle type could not be easily eliminated where they occurred in the soil litter of the trailer park, wooded areas, or roadside. Furthermore, only the capability to detect traces of copper separated lead rich particles in classes 20 and 21 from lead rich particles in classes 30 and 31 (Table 3-8). Similarly, only the capability to detect traces of zinc separated lead rich particles in classes 22 to 24 from lead rich particles in classes 20, 21, 30, and 31. In addition, the presence of phosphorus in these lead bearing particles did not prove to be useful for discriminating particle origin, as described later. Because traces of copper and zinc in these lead rich particles may have represented impurities in the original lead, as opposed to specific manufacturing processes and because of limitations in detecting trace elements in small particles, additional evaluation of these particles as a group was conducted. In contrast to copper and zinc, the presence of antimony, barium, and tin in lead bearing particles could be connected with specific manufacturing processes for automobile batteries. Thus, lead rich particles in particle classes 20 to 24, 30, and 31 were grouped together to determine the maximum extent to which particles in these particle classes in the soil litter of the trailer park may have been attributed to automobiles as opposed to automobile battery manufacturing. To accomplish this, the distribution of the number of particles in these particle classes (20-24, 30, 31) relative to the total number of lead bearing particles was compared between the soil of the trailer park and the soil of the roadside. As a group, lead rich particles in particle classes 20 to 24, 30, and 31 were designated lead "oxide" particles for simplification and: (1) because oxygen was detected as a major constituent in lead rich particles containing copper and phosphorous (class 20) and (2) because of the similarity noted above between lead rich particles in particle classes 20 to 24, 30, and 31. In fact, the lead "oxide" particles

in particle classes 20 to 24, 30, and 31 represented the other important general group of lead particle types found originating from the Exide facility.

Figure 4-12 compares the percentage of total lead bearing particles that were identified as lead "oxide" particles in each of 10 samples of trailer park soil litter and the same percentage in each of 10 samples of roadside soil litter. This comparison of lead "oxide" particle distributions in trailer park and roadside soil showed a sharp contrast. The lead "oxide" particles in the trailer park soil were distinctly more abundant relative to total lead bearing particles than was found in the roadside soil. This suggested the lead "oxide" particles found in the two areas were essentially from different sources. The median percentages of lead "oxide" particles for the trailer park and roadside soil litter were 41.5 and 0.0%, respectively. These median percentages were compared by the Mann-Whitney statistical test, described in more detail above in the Methods section. Results of this test showed a statistically significant ( $P = 0.0023$ ) difference in median percentages of lead "oxide" particles in the trailer park soil relative to the roadside soil at the 95% confidence level. P-values less than 0.05 indicated a statistically significant difference at the 95% confidence level between the medians of the two populations compared. P-values greater than or equal to 0.05 indicated no statistically significant difference between the medians of the two populations compared at the 95% confidence level. This result showed a statistically significant difference in the distribution of lead "oxide" particles relative to total lead bearing particles in the trailer park soil relative to the roadside soil. This was consistent with most of the lead "oxide" particles in the trailer park soil originating from the Exide facility and not from automobiles. The strong correlation of lead and antimony ( $r^2 = 0.88$ ) in the trailer park soil provided confirmation of this. Furthermore, lead "oxide" particles were only 6.3% of total lead bearing particles in the roadside soil overall compared to 54% in the trailer park soil, or approximately 8 to 9 times less common. This was consistent with the average lead concentration in the roadside soil being approximately 5 times less than that in the trailer park soil, as noted previously.

As noted above, two important general groups of lead particle types were found originating from the Exide facility, lead-antimony-tin particles (classes 1-4, 10-19) and lead "oxide" particles (classes 20-24, 30, 31). Differences in the relative abundances of these two general groups of lead particles were found between the Exide air filters, trailer park attic dust and soil litter, and wooded area soil litter (Figure 4-11). These differences were most likely the result of changes in the configuration and operational history of the Exide facility over several decades. Furthermore, the installation of PVC siding on the house in the trailer park may have modified the access for airborne particles into the attic. In addition, analytical results of the Exide air filters represented a "snap shot" in time of the processes which occurred at the Exide facility.

In a small number of lead bearing particles in process materials and dust from the Exide facility, barium was found (Figure 4-11, Table 3-8, classes 40-45). These data were consistent with barium sulfate being used in the negative battery paste in the manufacture of automobile batteries, but not with other possible sources such as automobile exhaust. Lead bearing particles containing barium were also found in small numbers in Exide soil litter and air filters, in the soil litter of the trailer park and wooded areas, but not in the more distant roadside soils, consistent with an origin from the Exide facility. Some of the lead bearing particles containing barium also contained antimony, copper, and/or tin, which further suggested an origin from the Exide facility, as described above. Thus, lead-barium particles represented a third, though relatively minor, general group of lead particle types originating from the Exide facility.

Phosphorous was detected in many of the lead bearing particles documented. Although phosphorous was found in many lead bearing particles in dust from the old grid plate casting area of the Exide facility and has been associated with automobile exhaust, weathering reactions in soil of phosphate with lead bearing particles after deposition may have been common. The greater abundance of lead bearing particles with phosphorous in soil than in attic dust or air filters was consistent with authigenic alteration of lead bearing particles with phosphate. Lead phosphate mineral phases have greater stability, i.e., lower solubilities, in surface soils than lead oxides, hydroxides, sulfates, or carbonates (Nriagu, 1984). Furthermore, Davis et al. (1993) found evidence of authigenic phosphate reactions with lead particles in soils impacted by mine waste. Therefore, because of likely widespread authigenic soil reactions involving lead and phosphate and despite the abundance of lead bearing particles containing phosphorous in the soil litter at the Exide facility, phosphorous was not considered to be indicative, i.e., a reliable predictor, of particle source.

Manganese occurred in lead rich particles in the soil litter of the trailer park, wooded areas, and roadside soil and also in manganese rich particles in the wooded areas and roadside soil (Figure 4-11, Table 3-8, classes 50-55). In addition, lead was found in iron rich particles in the roadside soil (class 100). The association of lead with manganese and iron in these particles was consistent with the product of weathering reactions in soil involving these elements. Davis et al. (1993) found abundant authigenic manganese lead oxides and less abundant authigenic iron lead oxides in soil impacted by mine waste. Levy et al. (1992) found soil lead predominantly associated with the iron and manganese oxide mineral phases in soil impacted by mine waste. In addition, Rauch et al. (2000) and Harrison et al. (1981) found lead associated with iron and manganese in road sediment. Although copper and/or zinc were present in particle class 53 and 54 lead particles, these particles were not easily attributable to the battery facility because manganese was not detected in any lead bearing particles from Exide. Except for the presence of chlorine in the class 52 particle, sources

of the lead-manganese, manganese-lead, and iron-lead particles found in this study could not be determined with any certainty due to the lack of otherwise distinguishing elemental characteristics.

Lead rich particles containing chlorine and copper (class 60), chromium (class 70), or sulfur (class 90) were found in roadside soil but not at the Exide facility (Figure 4-11, Table 3-8). Because these particles were not found at the Exide facility, they were not easily attributable to the battery facility. However, the presence of chlorine and sulfur in lead rich particles was consistent with lead from automobile exhaust, suggesting automobile exhaust as a likely source for those particles. Although bulk elemental analysis indicated paint was not a major source of lead in the roadside soil, the presence of chromium in lead rich particles was consistent with yellow centerline road paint (Fukuzaki et al., 1986; Fergusson and Kim, 1991), suggesting that as the source of the lead-chromium particles in roadside soil.

Particles containing primarily copper with a minor abundance of zinc and a trace to minor abundance of lead were common in roadside soil litter, were rare in trailer park soil litter, and were not found in soil litter of the Exide facility or wooded areas (Figure 4-11, Table 3-8, classes 80-82). These particles were consistent with a leaded brass material. Typically, brass is composed of approximately two-thirds copper and one-third zinc, with leaded brass containing approximately 3 weight percent lead (Breedis and Caron, 1998). Brass, copper, iron, zinc, and other metals have been commonly used in the manufacture of brake friction materials, and lead has been commonly used as a binder or modifier in such materials (Klein, 1969, NTIS, 1973; Jacko et al., 1984; Jacko and Rhee, 1998). Furthermore, in a study of road dirt particles, Mizohata et al (1995) identified one source of particles as metal powders of copper and brass mixed as inorganic filler in organic friction materials for brake systems. In fact, roadside soil cores, in which these particles were common, were collected near the intersection of Route 101 and Ansel School Road where a great deal of braking would be expected by turning vehicles. In addition, few of these particles were found in the soil litter of trailer park where there was little traffic and none were found in the soil litter of the Exide facility or wooded areas where there was virtually no traffic. For these reasons, brake friction materials were the most probable source of the copper rich, lead and zinc bearing particles found in the roadside soil. As noted previously, the presence of phosphorous in these particles was likely the result of weathering reactions in the soil. The presence of chlorine and sulfur in these particles may also have been the result of weathering reactions in the soil. The presence of chromium and nickel in one of these particles probably indicated additional brass alloying ingredients. Thus, these copper rich particles containing zinc and lead most likely represented vehicle brake lining wear dust.

Finally, because results of individual particle analysis of soil litter were consistent with correlations of bulk soil data (i.e., lead with antimony, copper, and tin), results of individual particle

analysis were found to be generally representative of the variety and general abundance of lead particle types present in soil litter samples. The vast majority of lead bearing particles in the soil litter of the trailer park, Exide facility, and wooded areas were traceable to the Exide facility as the source of these particles. This is clearly depicted in Figure 4-11. The relative proportion of lead bearing particles in each soil area attributed to specific sources is discussed further in the Apportionment section.

#### 4.4. Apportionment of Lead Contamination

Lead in the soil of the Westgate Trailer Park, Exide facility, adjacent wooded areas, and roadside was apportioned between identified sources using several different methods. These methods were based on the following: (1) the average bulk concentration of lead in the roadside soil litter relative to that in the other soil areas, (2) the ratio of average lead concentration to average bromine concentration in bulk soil litter along the roadside relative to the other soil areas, (3) the ratio of average lead concentration to average antimony concentration in bulk soil litter of the Exide facility relative to the other soil areas, and (4) the proportion of lead bearing particles associated with identified sources along with particle size and approximate lead content of these particles in the four soil areas.

Elemental concentrations in bulk soil provided a method to apportion lead in receptor soils to different sources. First, the amount of lead in receptor area soil litter attributable to naturally occurring background was estimated. A mean lead concentration of 21 mg/kg was reported for "A" horizon soil in northern Georgia (USGS, 1975). "A" horizon soil is the top soil layer typically consisting of soil litter. Assuming 21 mg/kg as the average natural background lead concentration in soil litter in the Greer area suggested most of the lead in receptor soil litter was attributable to anthropogenic contamination (Table 3-2). The difference between the average lead concentrations in receptor soil litter and a natural background lead concentration of 21 mg/kg gave the average concentrations of lead due to anthropogenic contamination in the receptor areas. The estimated proportions of lead due to natural background in receptor area soil litters were calculated using equation (1) below and are given in Table 4-4a.

$$\% \text{ Pb}_{\text{BG}} = ([\text{Pb}_{\text{BG}}]) / [\text{Pb}_{\text{RA}}] \times 100\% \quad (1)$$

where:  $\% \text{ Pb}_{\text{BG}}$  = percentage of lead in receptor soil attributable to natural background  
 $[\text{Pb}_{\text{BG}}]$  = concentration of natural background lead in soil litter (21 mg/kg)

[Pb<sub>RA</sub>] = average concentration of lead in the receptor area soil litter (trailer park, Exide, wooded areas, roadside) (Table 3-2)

The proportion of the average bulk concentration of lead in the roadside soil litter relative to that in the other soil areas afforded a means to estimate the maximum amount of lead which may be attributed to automobiles in receptor soils. The maximum proportion of lead attributable to automobiles in the soil litter of the trailer park, Exide facility, and wooded areas was determined using the following assumption. The maximum amount of lead which was attributable to automobiles in the soil litter of these areas was not greater than the average concentration of lead due to anthropogenic contamination in roadside soil (167 mg/kg - 21 mg/kg). This assumption was reasonable because of the much greater distances of the trailer park, Exide facility, and wooded areas from busy roadways than the roadside soil. These maximum proportions of lead attributable to automobiles were calculated using equation (2) below and are given in Table 4-4b.

$$\% \text{ Pb}_{\text{SRC}} = (([\text{Pb}_{\text{RD}}] - [\text{Pb}_{\text{BG}}]) / [\text{Pb}_{\text{RA}}]) \times 100\% \quad (2)$$

where.  $\% \text{ Pb}_{\text{SRC}}$  = percentage of lead in receptor soil attributable to a given source

[Pb<sub>RD</sub>] = average concentration of lead in the roadside soil litter (Table 3-2)

[Pb<sub>BG</sub>] = concentration of natural background lead in soil litter (21 mg/kg)

[Pb<sub>RA</sub>] = average concentration of lead in the receptor area soil litter (trailer park, Exide, wooded areas) (Table 3-2)

Results in Table 4-4b indicate most of the lead in the soil litter of the trailer park, Exide facility, and wooded areas did not originate from automobiles.

The concentration ratios of lead to bromine in the four soil areas provided another method to calculate the apportionment of lead in receptor soils to automobiles. This method used the ratio of average lead concentration (less natural background lead as given above) to average bromine concentration (less background bromine as given below) in roadside soil litter to estimate the amount of lead which may be attributed to automobiles in receptor soils. The median concentration of bromine in Exide soil litter (5.50 mg/kg) was taken to represent the approximate amount of bromine in local soil due to natural background concentrations plus the amount of bromine due to impacts from the Exide facility. The Exide soil cores were not expected to have been greatly impacted by automobile exhaust due to their distances from main roadways, as described earlier. The median concentration of bromine in Exide soil, as opposed to the average concentration, was considered a better estimate of the level of naturally occurring bromine plus Exide bromine in local soil. This was

because the median bromine concentration was expected to be more representative of the widespread impact of contributions of bromine from the Exide facility. However, because the impact of bromine from the Exide facility was expected to diminish with distance from the facility and because the median concentration of bromine in Exide soil included bromine from the facility, a natural background concentration for bromine of zero (0.0 mg/kg) was also assumed in order to bracket the actual proportion of lead attributed to automobile exhaust with a high and a low value. By using equation (3) below to compare the lead to bromine ratio in roadside soil with that in receptor soil, high and low estimates of the lead associated with automobiles in receptor soils were determined and are given in Table 4-4c.

$$\% \text{ Pb}_{\text{SRC}} = (([\text{Br}_{\text{RA}}] - [\text{Br}_{\text{BG}}])([\text{Pb}_{\text{SA}}] - [\text{Pb}_{\text{BG}}]) / ([\text{Br}_{\text{SA}}] - [\text{Br}_{\text{BG}}])([\text{Pb}_{\text{RA}}])) \times 100\% \quad (3)$$

where.  $\% \text{ Pb}_{\text{SRC}}$  = percentage of lead in receptor soil attributable to a given source

$[\text{Br}_{\text{RA}}]$  = average concentration of bromine in the receptor area soil litter (trailer park, Exide, wooded areas) (Table 3-2)

$[\text{Br}_{\text{BG}}]$  = concentration of background bromine in soil litter (0.0 - 5.50 mg/kg)

$[\text{Pb}_{\text{SA}}]$  = average concentration of lead in the source area soil litter (roadside)  
(Table 3-2)

$[\text{Pb}_{\text{BG}}]$  = concentration of natural background lead in soil litter (21 mg/kg)

$[\text{Br}_{\text{SA}}]$  = average concentration of bromine in the source area soil litter (roadside)  
(Table 3-2)

$[\text{Pb}_{\text{RA}}]$  = average concentration of lead in the receptor area soil litter (trailer park, Exide, wooded areas) (Table 3-2)

Using either high or low bromine concentrations for the assumed background level, results in Table 4-4c indicate little of the lead in the soil litter of the trailer park, Exide facility, and wooded areas originated from automobiles.

Similar to the previous approach, concentration ratios of lead to antimony in the four soil areas provided a method to calculate apportionment of lead in receptor soils to the Exide facility. This method used the ratio of average lead concentration (less natural background lead as given above) to average antimony concentration (less natural background antimony as given below) in Exide soil litter to estimate the amount of lead which may be attributed to the Exide facility in receptor soils. Because the roadside soil was not expected to have been greatly impacted by the Exide facility due to its distance from the facility, the median concentration of antimony in roadside soil litter (0.53 mg/kg) was taken as the approximate natural background antimony concentration in local soil litter. The median concentration of antimony in the roadside soil, compared to the average



concentration, was considered a better approximation of naturally occurring antimony levels. This was because the median concentration was not as affected by any soil litter samples which may have been impacted by anthropogenic activities. However, because some impact by anthropogenic activities along the roadside was likely, the median antimony concentration along the roadside was probably still higher than the actual naturally occurring antimony concentration. Therefore, a natural background concentration for antimony of zero (0.0 mg/kg) was also assumed in order to bracket the actual proportion of lead attributed to the Exide facility with a high and a low value. By using equation (4) below to compare the lead to antimony ratio in Exide soil with that in receptor soil, high and low estimates of lead associated with the Exide facility in receptor soils were determined and are given in Table 4-4d.

$$\% \text{ Pb}_{\text{SRC}} = (([\text{Sb}_{\text{RA}}] - [\text{Sb}_{\text{BG}}])([\text{Pb}_{\text{SA}}] - [\text{Pb}_{\text{BG}}]) / ([\text{Sb}_{\text{SA}}] - [\text{Sb}_{\text{BG}}])([\text{Pb}_{\text{RA}}])) \times 100\% \quad (4)$$

where:  $\% \text{ Pb}_{\text{SRC}}$  = percentage of lead in receptor soil attributable to a given source

$[\text{Sb}_{\text{RA}}]$  = average concentration of antimony in the receptor area soil litter (trailer park, wooded areas, roadside) (Table 3-2)

$[\text{Sb}_{\text{BG}}]$  = concentration of natural background antimony in soil litter  
(0.0 - 0.53 mg/kg)

$[\text{Pb}_{\text{SA}}]$  = average concentration of lead in the source area soil litter (Exide)  
(Table 3-2)

$[\text{Pb}_{\text{BG}}]$  = concentration of natural background lead in soil litter (21 mg/kg)

$[\text{Sb}_{\text{SA}}]$  = average concentration of antimony in the source area soil litter (Exide)  
(Table 3-2)

$[\text{Pb}_{\text{RA}}]$  = average concentration of lead in the receptor area soil litter (trailer park, wooded areas, roadside) (Table 3-2)

Using either high or low antimony concentrations for the assumed natural background level, results in Table 4-4d indicate most of the lead in the soil litter of the trailer park, Exide facility, and wooded areas originated from the Exide facility. No estimate was calculated for the roadside soil due to the lack of correlation between lead and antimony in bulk soil analyses and the lack of lead-antimony-tin particles in individual particle analysis.

Results of individual particle analysis were consistent with correlations of bulk soil lead concentrations with antimony, copper, and tin, suggesting individual particle analysis was generally representative of the variety and general abundance of lead particle types present in soil litter samples. Therefore, results of individual particle analysis (Table 3-8) were applicable to source apportionment of lead in receptor soil. Using these findings, the apportionment of lead in the soil

of the trailer park, Exide facility, wooded areas, and roadside was determined in three steps. First, lead was apportioned between sources by a count of lead bearing particles from sources as identified in the Individual Particle Analysis section and Table 3-8. Equation (5) was used for this step, giving a source apportionment based on particle count, i.e., the percent of total lead bearing particles that were identified with a given source (Table 4-5a)

$$\% \text{ Pb}_{\text{SRC}} = ((N_{\text{SRC}}) / (N_{\text{TOTAL}})) \times 100\% \quad (5)$$

where  $\% \text{ Pb}_{\text{SRC}}$  = percentage of lead in receptor soil attributable to a given source based on lead bearing particle count

$N_{\text{SRC}}$  = number of all lead bearing particles **associated with a given source** in the receptor area soil litter (Table 3-8)

$N_{\text{TOTAL}}$  = **total** number of lead bearing particles in the receptor area soil litter (Table 3-8)

Second, to estimate differences due to particle size, the longest diameter of all lead bearing particles (Appendix C) that were identified with a given source were summed. Equation (6) was used for this step, giving a source apportionment based on particle size (Table 4-5b).

$$\% \text{ Pb}_{\text{SRC}} = ((\Sigma_{\text{SRC}} \text{ PT}_{\text{LD}}) / (\Sigma_{\text{TOTAL}} \text{ PT}_{\text{LD}})) \times 100\% \quad (6)$$

where.  $\% \text{ Pb}_{\text{SRC}}$  = percentage of lead in receptor soil attributable to a given source based on lead bearing particle size

$\Sigma_{\text{SRC}} \text{ PT}_{\text{LD}}$  = sum of the longest diameters,  $\text{PT}_{\text{LD}}$ , for all lead bearing particles **associated with a given source** in the receptor area soil litter (Appendix C)

$\Sigma_{\text{TOTAL}} \text{ PT}_{\text{LD}}$  = sum of the longest diameters,  $\text{PT}_{\text{LD}}$ , for **all** lead bearing particles in the receptor area soil litter (Appendix C)

$\text{PT}_{\text{LD}}$  = longest diameter of a given particle (Appendix C)

Finally, the weight percent of lead in soil attributed to identified sources was estimated using the average lead content in particles for the lead particle classes found in the trailer park, wooded areas, and roadside (Table 3-9). The average lead content for the particle class of a given particle in a given receptor soil was multiplied by the particle's longest diameter. The best estimate of the lead content in a given lead particle was the average lead content in the appropriate particle class and

receptor soil, as given in Table 3-9. Equation (7) was used for this last step, giving a source apportionment based on the weight percent of lead (Table 4-5c).

$$\% \text{ Pb}_{\text{SRC}} = ((\Sigma_{\text{SRC}} [\text{Pb}_{\text{PT}}] \times \text{PT}_{\text{LD}}) / (\Sigma_{\text{TOTAL}} [\text{Pb}_{\text{PT}}] \times \text{PT}_{\text{LD}})) \times 100\% \quad (7)$$

where  $\% \text{ Pb}_{\text{SRC}}$  = percentage of lead in receptor soil attributable to a given source based on weight percent

$\Sigma_{\text{SRC}} [\text{Pb}_{\text{PT}}] \times \text{PT}_{\text{LD}}$  = sum of the products,  $[\text{Pb}_{\text{PT}}] \times \text{PT}_{\text{LD}}$ , for all lead bearing particles associated with a given source in the receptor area soil litter

$\Sigma_{\text{TOTAL}} [\text{Pb}_{\text{PT}}] \times \text{PT}_{\text{LD}}$  = sum of the products,  $[\text{Pb}_{\text{PT}}] \times \text{PT}_{\text{LD}}$ , for all lead bearing particles in the receptor area soil litter

$[\text{Pb}_{\text{PT}}]$  = estimated average concentration of lead in a given particle class in the receptor area soil litter (Table 3-9)

$\text{PT}_{\text{LD}}$  = longest diameter of a given particle (Appendix C)

Similar methods of apportionment using individual particle analysis are found in the literature (Heasman and Watt, 1989; Hopke, 1991; Currie, 1992; Davis et al, 1993). In addition, Currie (1992) found particle class apportionment offered greater resolution relative to bulk particle source apportionment.

As noted earlier, lead "oxide" particles (classes 20-24, 30, 31) and their potential sources were not necessarily clearly distinguished. Therefore, the source apportionment of lead "oxide" particles in the trailer park and wooded areas was achieved using the percentage of lead "oxide" particles attributable to automobile exhaust, as determined in the Individual Particle Analysis section. This percentage was based on individual particle analysis of lead bearing particles in roadside soil litter. Thus, 6.3% of the total lead bearing particles not including the lead-antimony-tin particles (classes 1-4, 10-19) in a receptor soil was the percentage of lead "oxide" particles apportioned to automobile exhaust. The remaining portion of lead "oxide" particles was apportioned to the Exide battery facility. The application of this percentage of 6.3 to lead "oxide" particles in trailer park and wooded area soil was probably a maximum percentage based on the combination of: (1) the greater lead concentrations in the trailer park and wooded area soil compared to the roadside soil, and (2) the greater distances from the main roadways to much of the trailer park and wooded areas relative to the roadside soil. Finally, for all practical purposes, nearly all lead "oxide" particles in the Exide soil were considered to originate from the Exide facility due to the combination of: (1) the proximity of the Exide soil to the main Exide building, (2) the greater distance from the main roadway to the Exide soil relative to the roadside soil, and (3) the extremely high lead concentrations found in the Exide soil.

By particle count, results of individual particle analysis indicated approximately 91% of lead bearing particles in the soil litter of the trailer park and 89% in the wooded areas originated from the Exide facility. By particle size, results of individual particle analysis indicated approximately 91% of lead bearing particles in the soil litter of the trailer park and 60% in the wooded areas originated from the Exide facility. Finally, the estimated weight percent of lead from the Exide facility in the soil litter of the trailer park was 93% and in the wooded areas, 79%. The last two results for the wooded area soil appeared to be biased low due to the relatively high impact of a single particle in a relatively small sample set of lead bearing particles ( $n = 37$ ). In contrast, relatively little lead due to automobile exhaust was found in the trailer park and wooded area soil. Also, no lead bearing particles from the Exide facility were clearly recognized in the roadside soil. These results indicated most of the lead in both the trailer park and the wooded areas originated from the Exide facility.

General agreement was found in the above approaches to lead apportionment. Apportionment results based on bulk soil analysis may be considered more representative of the sources of lead in receptor soils overall because they were based on more extensive sampling. However, results based on individual particle analysis provided greater resolution of the sources of lead in receptor soils, allowing additional though relatively minor sources of lead to be identified. Data from individual particle analysis, average bulk soil lead concentrations, and lead to bromine ratios all indicated the proportion of lead attributable to automobile exhaust in the soil of both the trailer park and the wooded areas was relatively small. In contrast, data from individual particle analysis, average bulk soil lead concentrations, and lead to antimony ratios all indicated the majority of the lead in the soil of both the trailer park and wooded areas was attributable to the Exide facility. Furthermore, these results were consistent with the high degree of correlation between lead and antimony in the soil litter of the Exide facility, trailer park, and wooded areas ( $r^2 = 0.98, 0.88, \text{ and } 0.94$ , respectively), which also indicated most of the lead in these areas was attributable to the Exide facility, as described previously. Finally, if a maximum of 167 mg/kg of lead on average could have been attributable to automobile exhaust in trailer park soil litter, then the Exide facility was responsible for all lead in trailer park soil litter in excess of either a 400 or 500 mg/kg clean up level.

#### **4.5. Recommendations for Soil Remediation in the Westgate Trailer Park**

The variability of lead concentrations in the trailer park was considered to determine which areas of the trailer park may require remediation at either a 400 or 500 mg/kg clean up level and to what depth any remediation of soil should take place.

#### 4.5.1. Extent of Soil Remediation

As indicated previously, high concentrations of lead were found in the soil litter in much of the trailer park. Results given previously (Table 3-1) also showed large variations in lead concentrations between and within circular areas represented by sets of soil cores. Relative standard deviations (RSD) as high as 49% within circular areas sampled indicated large variations in lead concentrations over relatively short distances. For example, lead concentrations in soil core set 10A-10D (RSD = 49%) ranged from 549 to 1310 mg/kg over a distance of 1.4 meters (4.6 feet). Furthermore, lead concentrations with a relative standard deviation of 47% within the circular area represented by soil core set 11A-11D ranged from 321 to 876 mg/kg over a distance of 0.94 meters (3.1 feet).

Table 3-1 shows the upper and lower confidence limits of mean lead concentration in areas of soil litter represented by sets of four soil cores. The upper confidence limits of the mean could not distinguish any of the 7.3 square meter (79 square feet) circular areas sampled in the trailer park where the average lead concentration was below 400 mg/kg at 95% confidence. In other words, variations in lead concentrations were too great over short distances (less than a meter) to distinguish areas of soil greater than approximately 7 square meters with lead concentrations below a threshold level of 400 mg/kg with any reasonable confidence.

Furthermore, results of soil core set 11A-11D indicated that to be 95% confident the average lead concentration in a 7.3 square meter (79 square feet) area of trailer park soil litter was below 544 mg/kg, the maximum lead concentration allowable in a 5.1 centimeter (2 inch) diameter soil core from the trailer park was 138 mg/kg, the lower confidence limit. Since the lowest lead concentration in the 80 soil litter samples collected in the trailer park was 287 mg/kg, no area of soil litter with an average lead concentration below 500 mg/kg could be distinguished from a single soil core. Therefore, based on a lead threshold level of 500 mg/kg and without any further sampling, the entire area of the trailer park must be remediated with the possible exception of the northeast area which has previously undergone remediation activity.

The magnitude of the heterogeneity of lead results from nearby soil cores has important implications for any future investigation undertaken to distinguish areas of the trailer park that may not require remediation. Standard practice is to characterize areas of concern, such as individual yards, with a single core taken in the center of the yard. Assuming that the heterogeneity observed in this study is typical throughout the yard or other area of concern, lead results for soil litter from a single core must be substantially below a given clean-up level to ensure that significantly higher lead concentrations do not occur nearby. Since results from a single soil core is a poor predictor of

lead levels from soil cores taken nearby, its use is not recommended for distinguishing areas of the trailer park that may not require remediation.

Therefore, based on a threshold level of either 400 or 500 mg/kg and without additional and comprehensive sampling, the entire area of the trailer park must be remediated with the possible exception of the northeast area which had previously undergone remediation activity. The limited soil removal action previously taken on the northeastern side of the trailer park was not sampled nor considered in this study.

#### **4.5.2. Depth of Soil Remediation**

As indicated above, measurements of the seven soil cores in the trailer park selected in a systematic random manner indicated a wide variation in the thickness of the soil litter layer there, from 0.5 to 7 centimeters (0.2 to 3 inches) thick (Table 3-3b). Because the thickness of the soil litter layer varied and was typically less than 7 centimeters (3 inches), concentrations of lead in the underlying mineral soil should be considered in determining the depth of soil to remediate in the trailer park. Results reported in Table 3-3a also indicated concentrations of lead over 400 mg/kg in the "lower" mineral soil in three out of seven soil cores, or 43% of samples. Two of these were over 500 mg/kg, or 29% of samples. One of these was over 1000 mg/kg. Such a pattern was consistent with the long term transport of lead from upper soil layers to underlying soil layers found by Miller and Friedland (1994) and Mason et al. (1999). Because of the high proportion of high lead concentrations in the "lower" mineral soil which included soil to a depth of 15.2 centimeters (6 inches), remediation of soil in the trailer park down to a depth of at least 15.2 centimeters should be considered.

## **5. CONCLUSIONS**

From the results of this study, conclusions were drawn concerning the presence, transport, sources, and apportionment of any anthropogenic lead contamination in the Westgate Trailer Park and other areas in the study. Additional conclusions concerned the remediation of the soil in the trailer park.

### **5.1. Lead Contamination in the Westgate Trailer Park and Other Areas**

(1) Most of the lead in the attic dust and soil in the Westgate Trailer Park, in the soil at the Exide facility, in the soil in the adjacent wooded areas, and in the soil along the roadside was the result of anthropogenic contamination.

### **5.2. Mode of Transport of Lead Contamination**

(1) Most of the lead in the attic dust and in the soil of the Westgate Trailer Park, Exide facility, adjacent wooded areas, and roadside was the result of airborne deposition.

### **5.3. Sources of Lead Contamination**

(1) The primary source of lead contamination in the attic dust of the Westgate Trailer Park and in the soil of the Exide facility, trailer park, and adjacent wooded areas was lead from the Exide facility.

(2) Two important general groups of lead particle types comprised lead contamination originating from the Exide facility. lead-antimony-tin particles and lead "oxide" particles.

(3) The primary source of lead contamination in soil along the roadside was automobile exhaust. Minor sources of lead contamination in soil along the roadside were vehicle brake lining wear dust and yellow centerline road paint.

#### **5.4. Apportionment of Lead Contamination**

- (1) Eighty percent or more of the lead contamination in the soil of the Westgate Trailer Park and adjacent wooded areas originated from the Exide battery facility.
- (2) No more than 18% and probably less than 13% percent of the lead contamination in the Westgate Trailer Park and nearby wooded areas originated from automobile exhaust.
- (3) Less than approximately 3% of the lead in the soil of Westgate Trailer Park and adjacent wooded areas was naturally occurring.

#### **5.5. Westgate Trailer Park Soil Remediation**

- (1) The variability of lead concentrations in the soil litter in the Westgate Trailer Park indicated that a single sampling of soil representing an area of soil approximately 7 square meters (75 square feet) or greater in size was not adequate to determine whether that area of soil, on average, was below a lead concentration of either 400 or 500 mg/kg. Therefore, the variability of lead concentrations in the soil litter of the trailer park was too great for soil areas of approximately 7 square meters or less to be omitted from remediation based on a single typical soil sample.
- (2) Because of the variability of lead concentrations in the soil litter in the Westgate Trailer Park over short distances (less than approximately 1 meter), an extensive sampling of trailer park soil would be required to delineate areas of soil below an average lead concentration of either 400 or 500 mg/kg which could be omitted from remediation. Without the necessary extensive soil sampling, the entire soil area of the trailer park must be remediated.
- (3) High concentrations of lead in the "lower" mineral soil which included soil to a depth of 15.2 centimeters (6 inches) indicated remediation of soil in the trailer park down to a depth of at least 15.2 centimeters should be considered.



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**FIGURES**

Figure 1-1. On following page. Site location map, Greer, South Carolina.

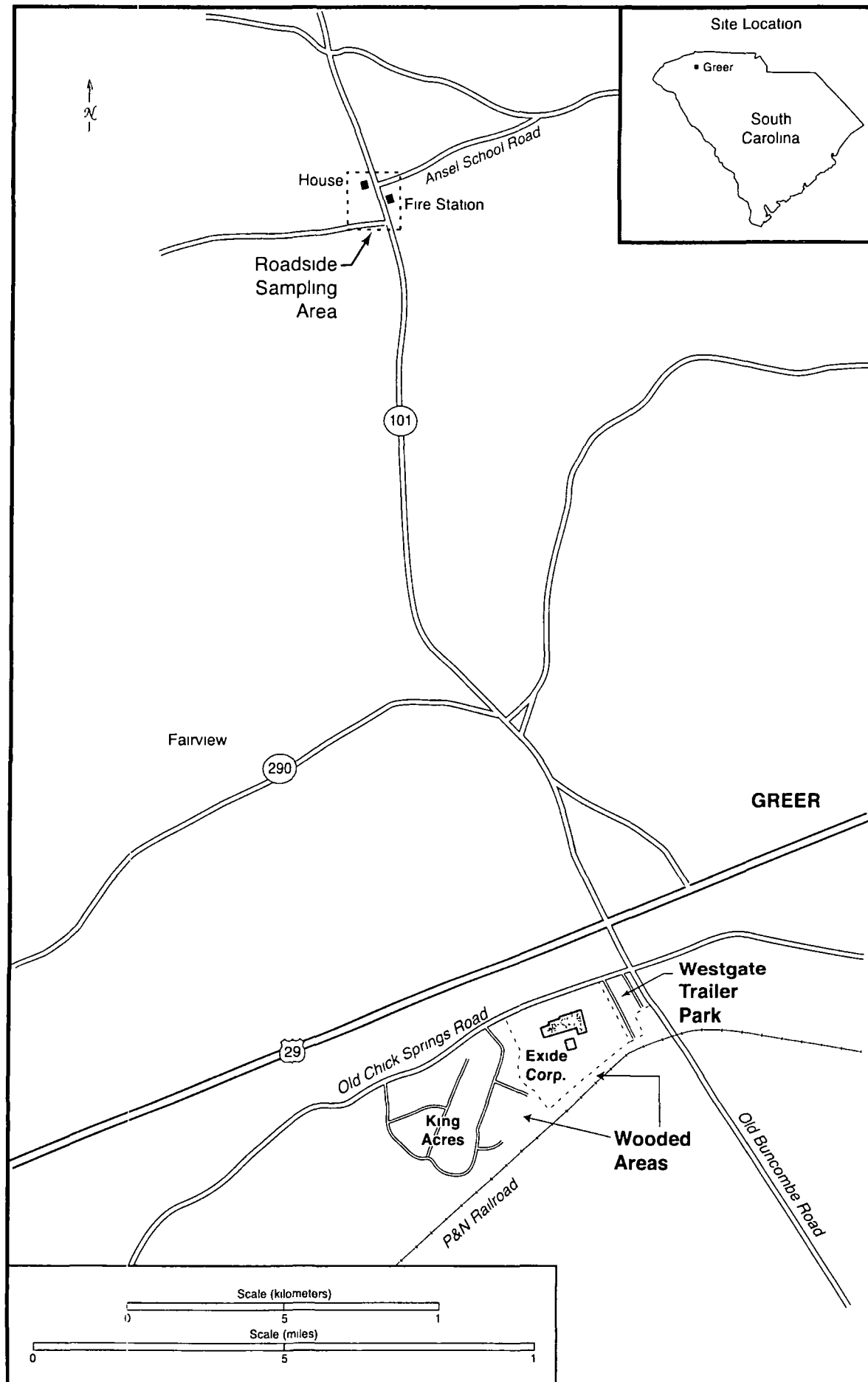


Figure 1-1  
SITE LOCATION MAP  
Greer, South Carolina

Figure 1-2. On following page. Map of the Westgate Trailer Park, Exide facility, and adjacent areas in Greer, South Carolina. Map after Webb (1997).

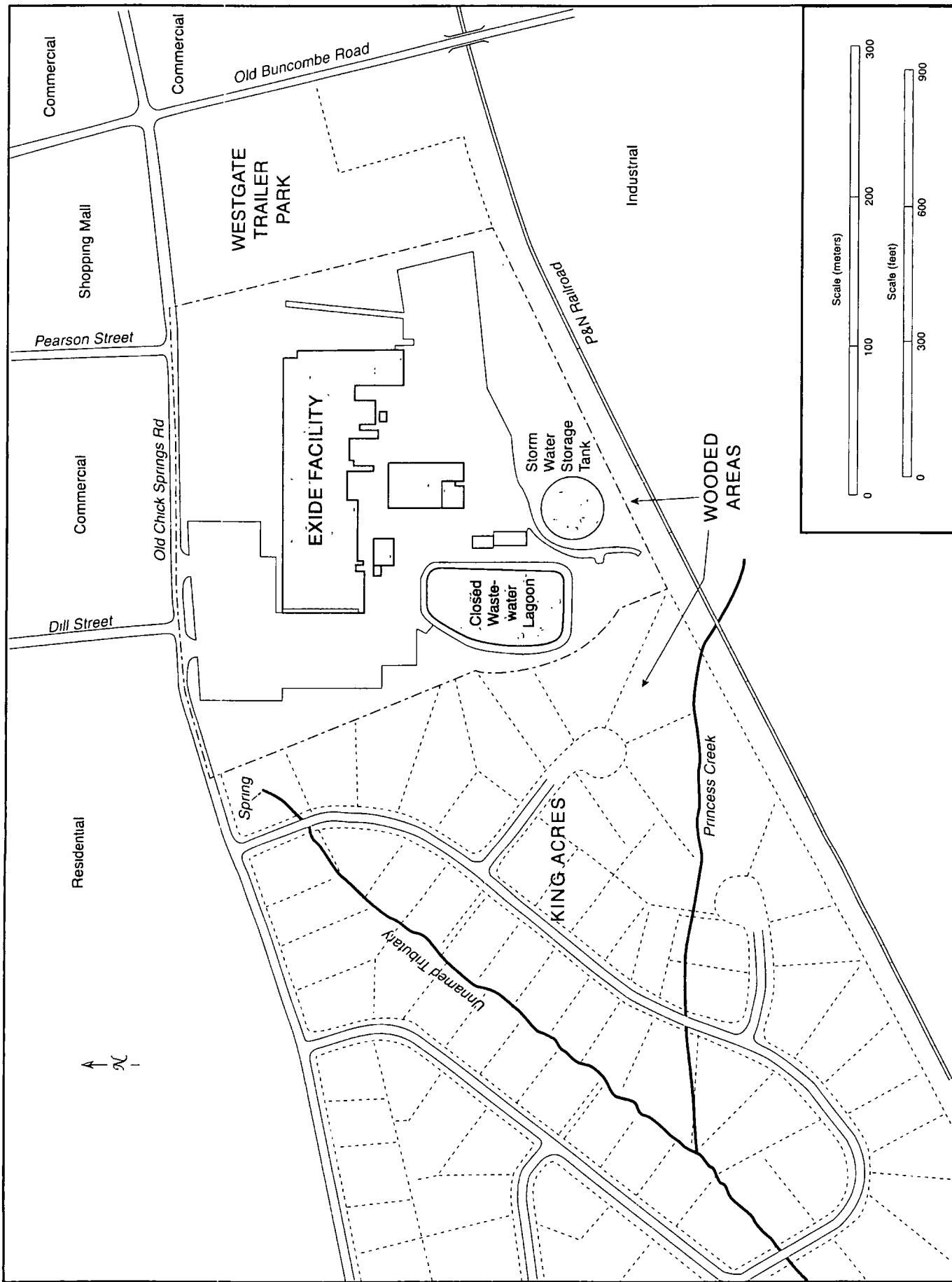


Figure 1-2  
THE WESTGATE TRAILER PARK, EXIDE FACILITY, AND SURROUNDING AREA  
Greer, South Carolina



Figure 2-1. On following page. Template dimensions for soil core sampling.

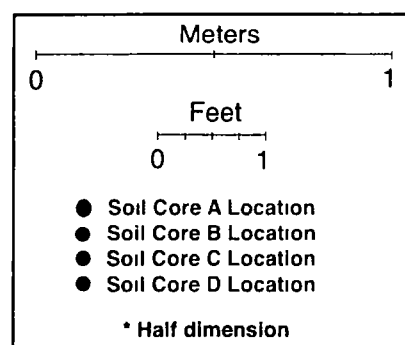
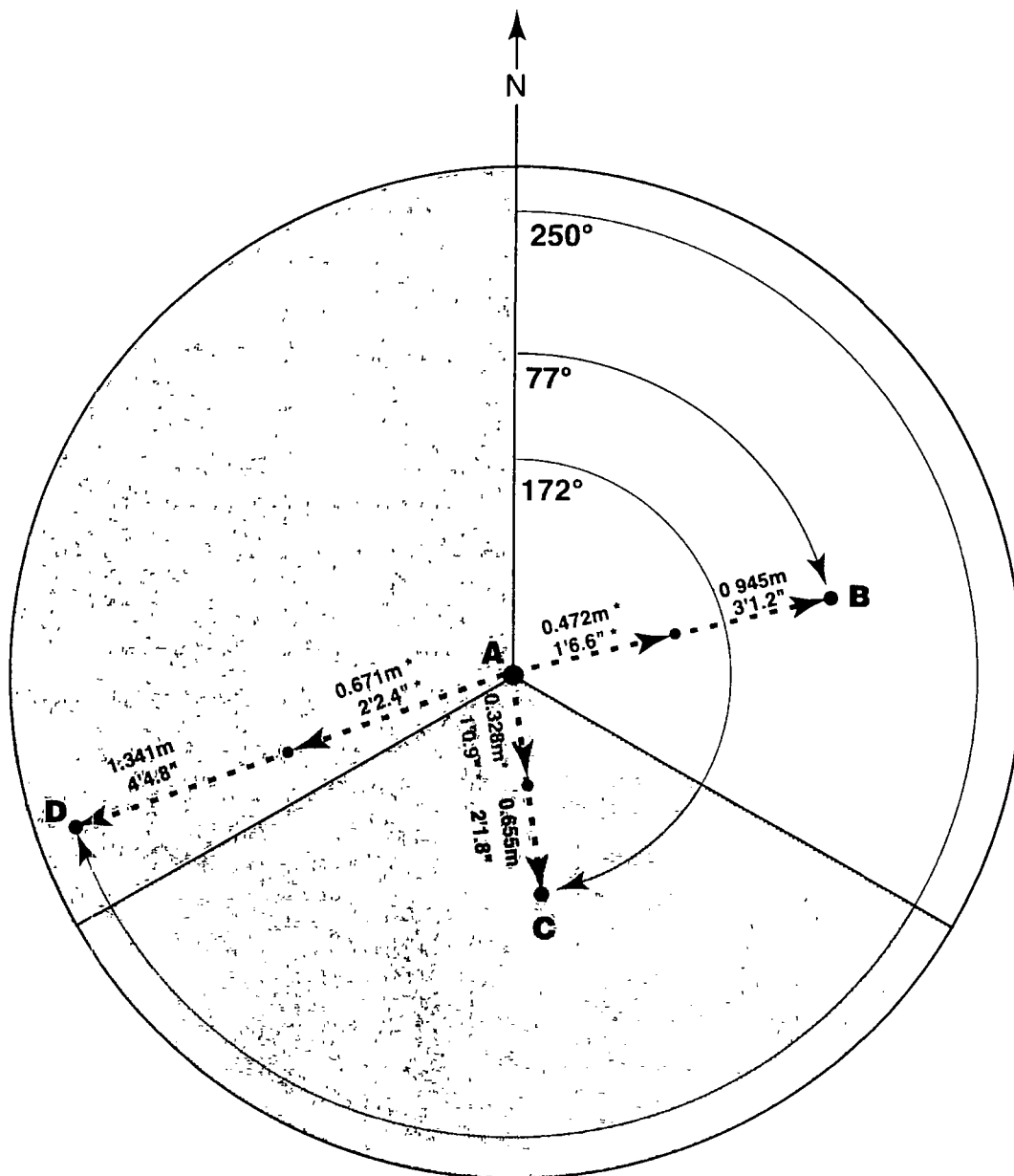


Figure 2-1  
 TEMPLATE DIMENSIONS FOR  
 SOIL CORE SAMPLING

Figure 2-2. On following page. Soil core and attic dust sample locations in the Westgate Trailer Park. Map after Webb (1997).



Figure 2-3. On following page. Process material, dust, and soil core sample locations at the Exide facility. Map after Webb (1997).

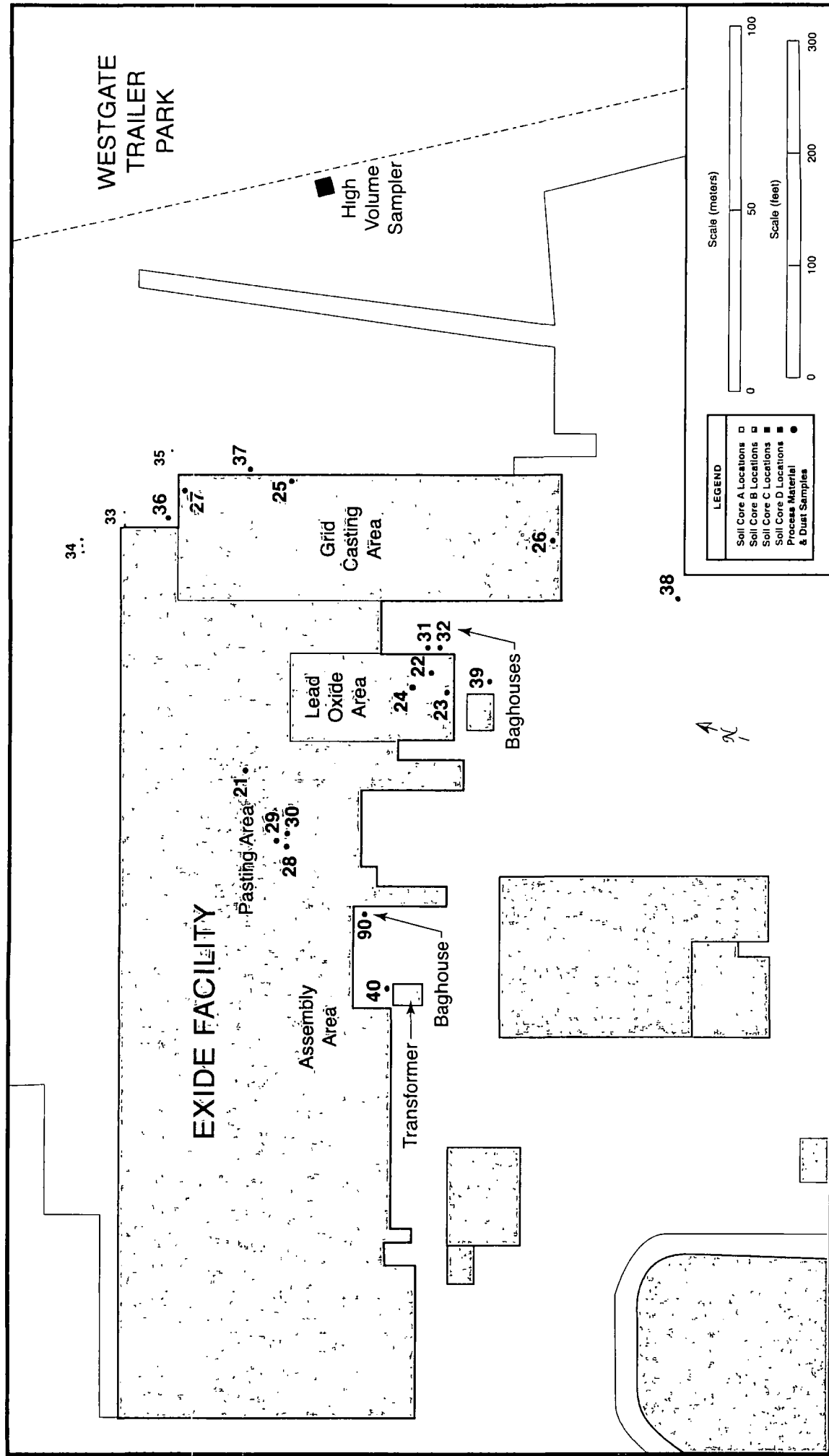


Figure 2-3  
 SOIL CORE LOCATIONS AND APPROXIMATE PROCESS MATERIAL AND DUST  
 SAMPLE LOCATIONS AT THE EXIDE FACILITY  
 Greer, South Carolina

Figure 2-4. On following page. Soil core sample locations in wooded area in the King Acres Subdivision adjacent to the Exide facility. Map after Webb (1997).

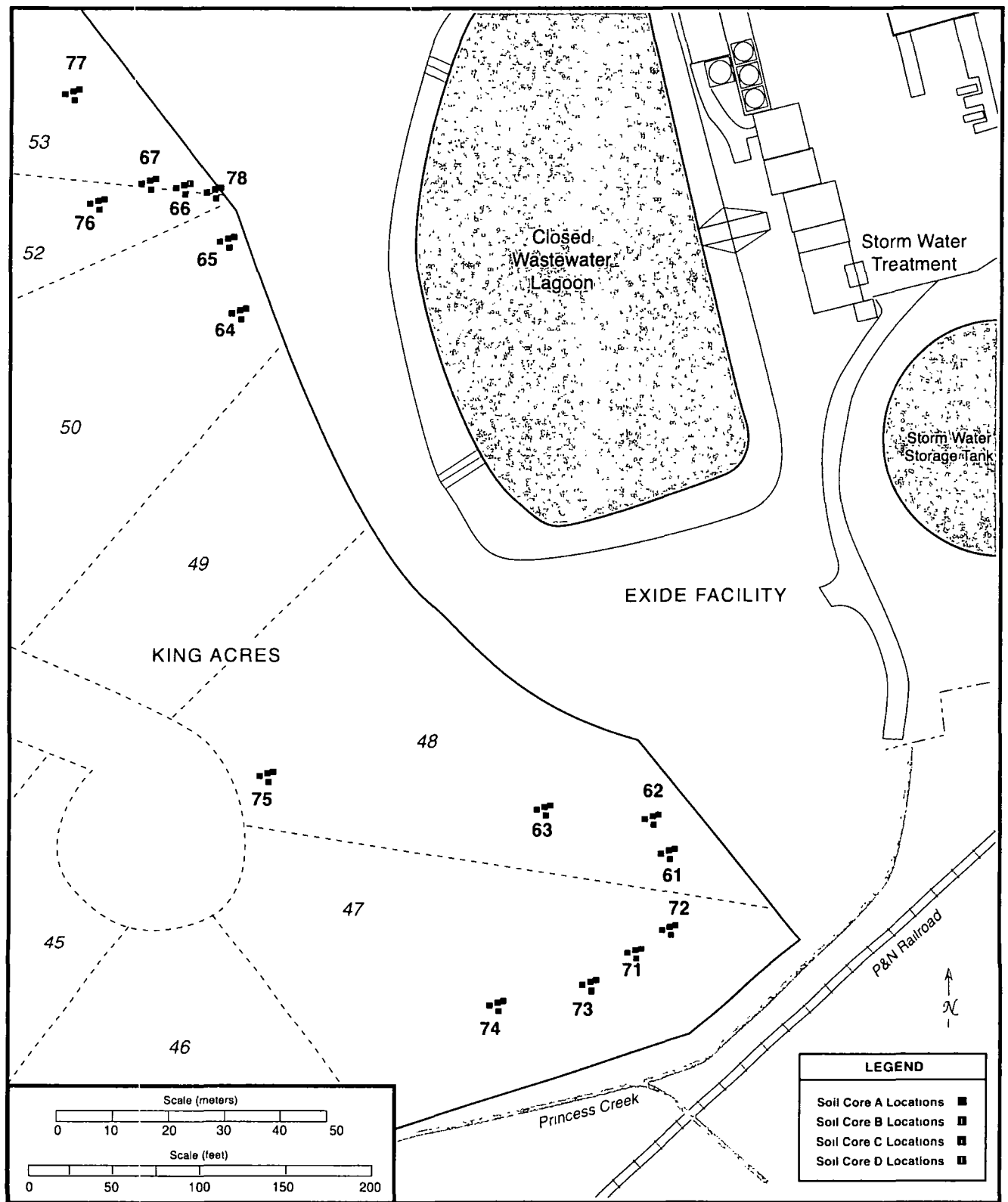


Figure 2-4  
SOIL CORE LOCATIONS IN WOODED AREA  
King Acres Subdivision  
Greer, South Carolina



Figure 2-5. On following page. Soil core sample locations in wooded area along railroad tracks adjacent to the Exide facility and the Westgate Trailer Park. Map after Webb (1997).

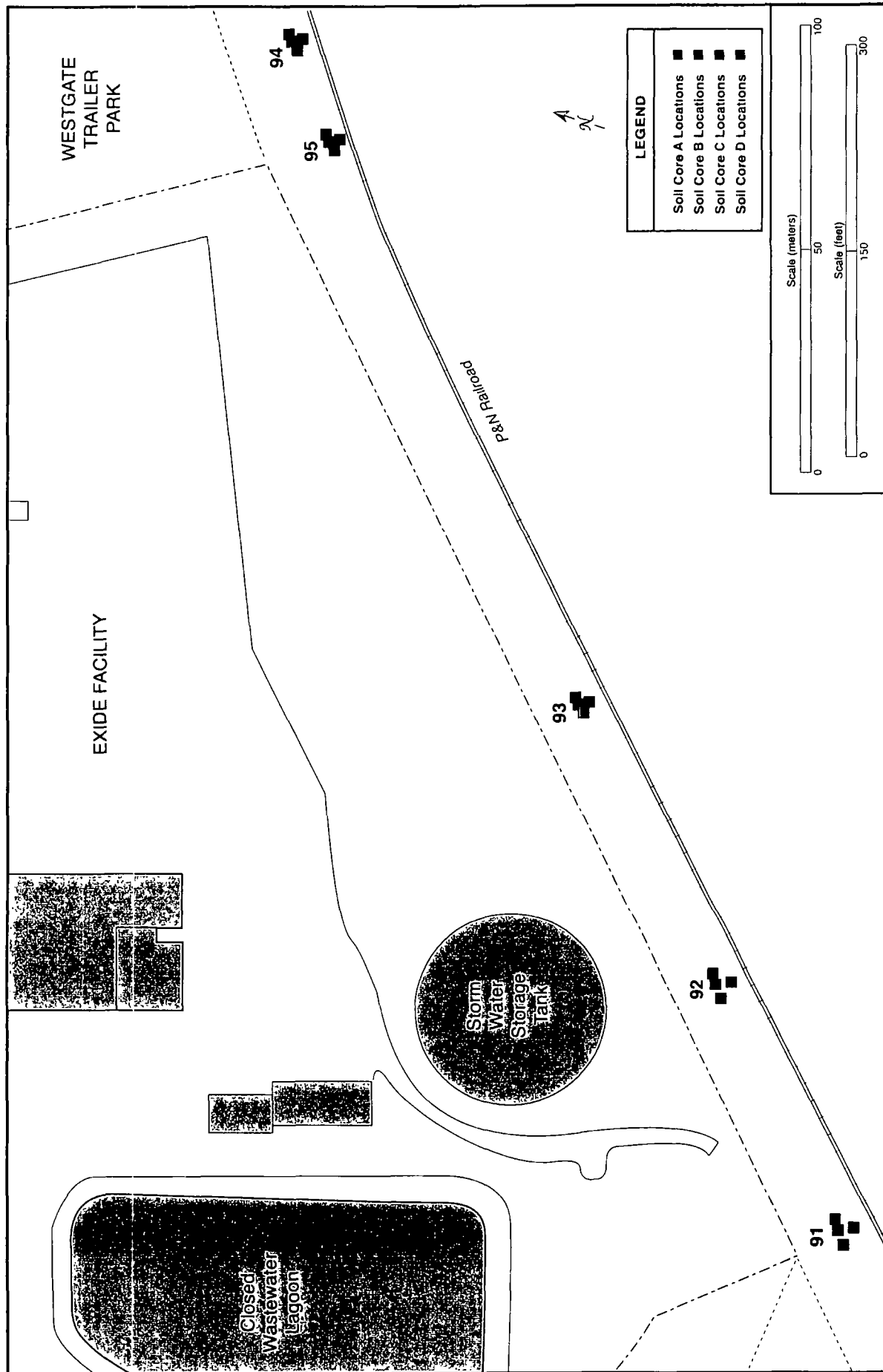


Figure 2-5  
 SOIL CORE LOCATIONS  
 IN WOODDED AREA ALONG RAILROAD  
 Greer, South Carolina

Figure 2-6. On following page. Soil core sample locations along Highway 101.

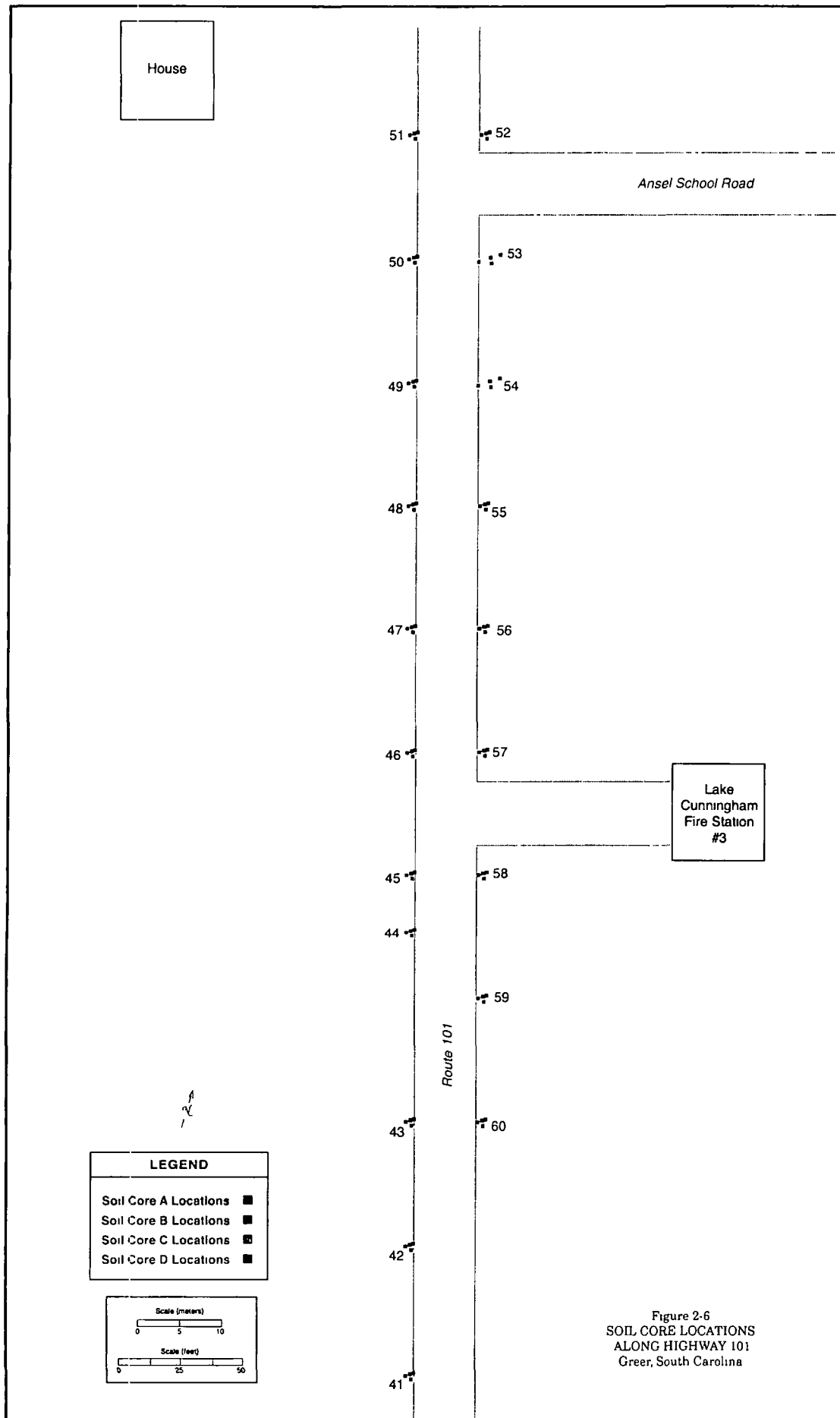


Figure 3-1. On following page. **Lead** concentrations in soil litter and attic dust in the Westgate Trailer Park in mg/kg. Map after Webb (1997).

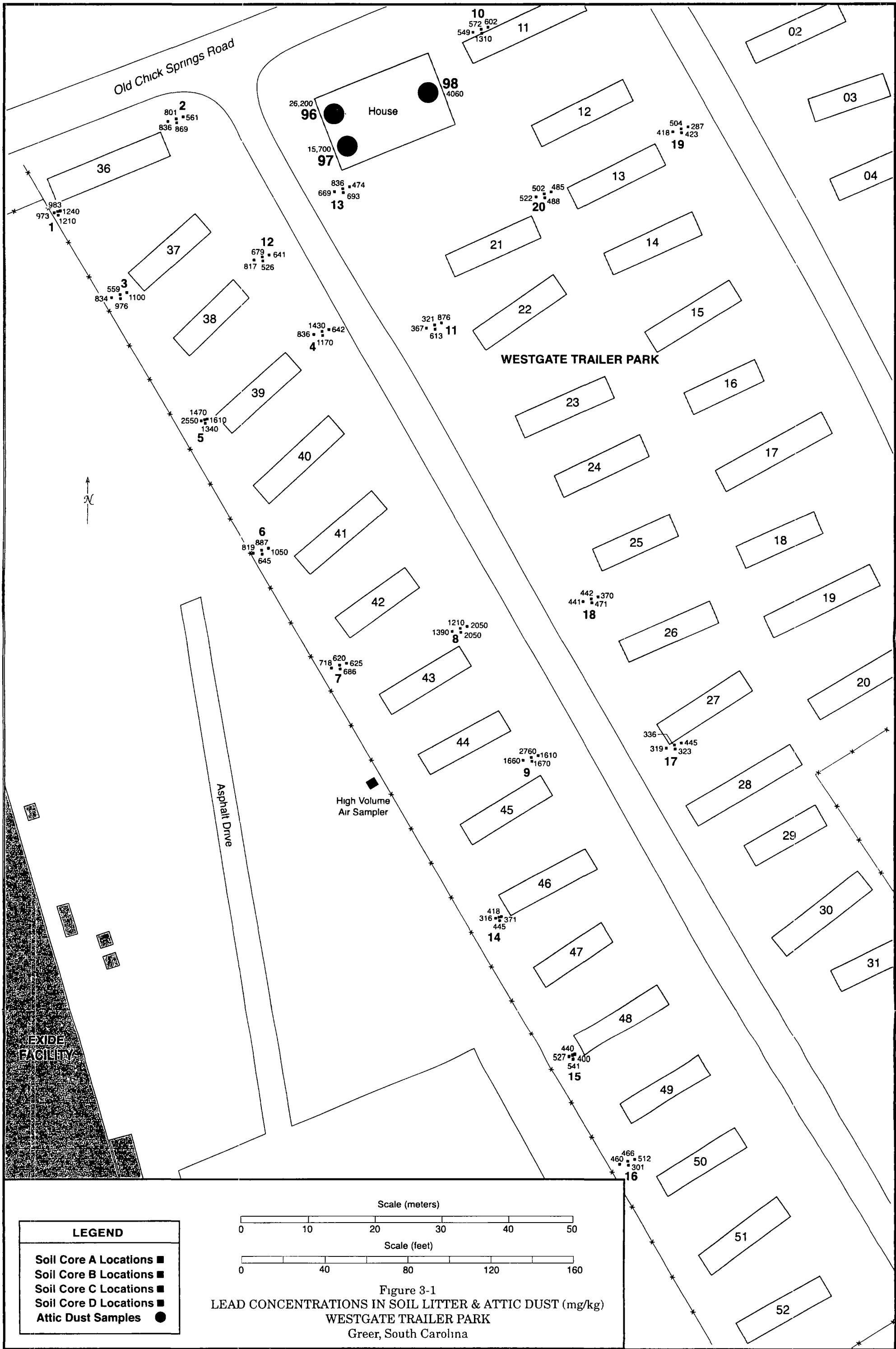


Figure 3-2a. On following page. **Lead** concentrations in soil litter at the Exide facility in mg/kg. Map after Webb (1997).

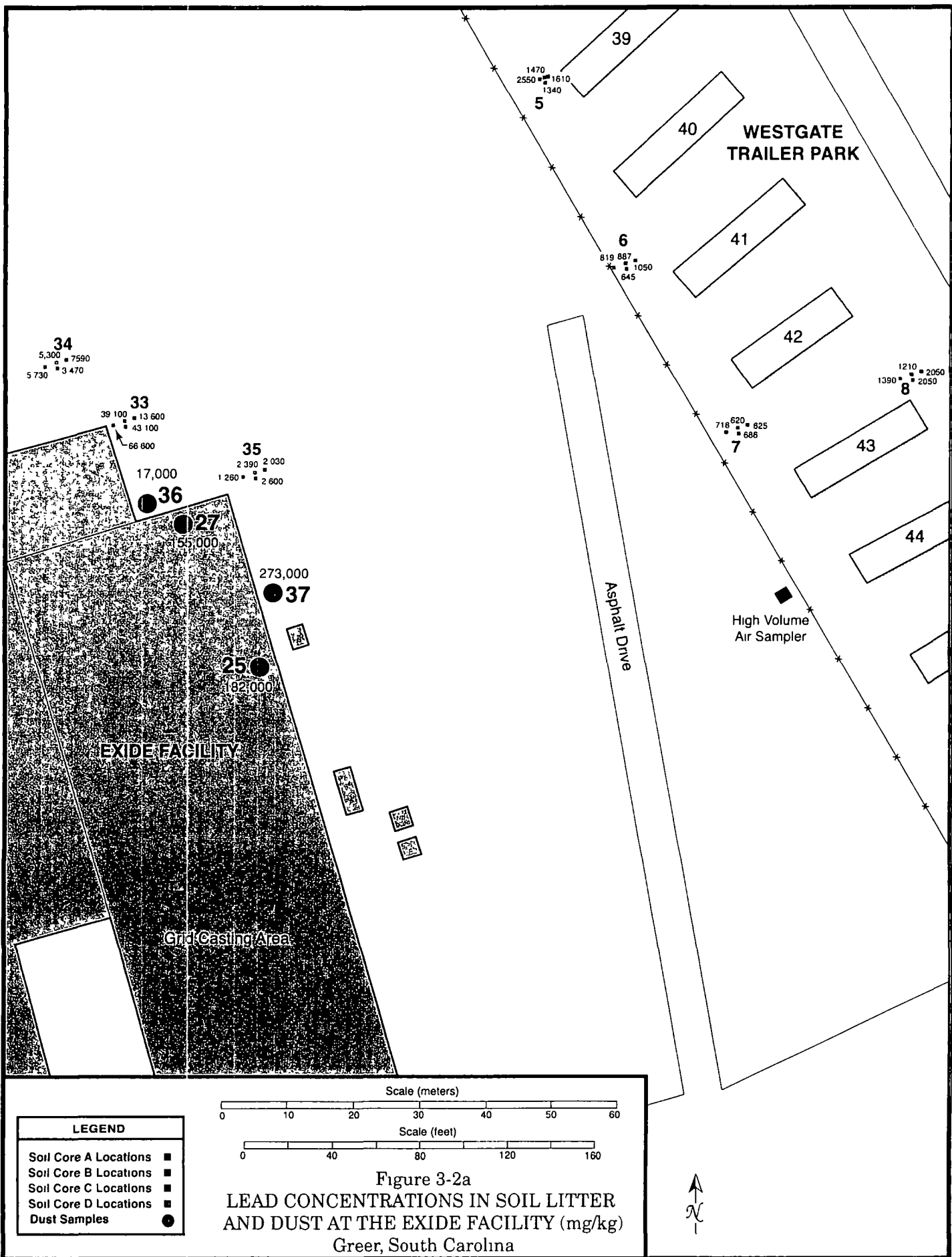
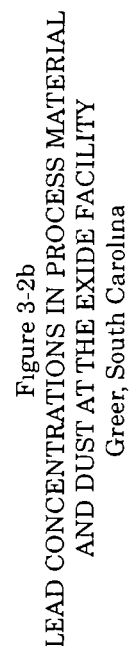




Figure 3-2b. On following page. **Lead** concentrations in process materials and dust samples at the Exide facility in mg/kg. Map after Webb (1997).



### LEAD CONCENTRATIONS IN PROCESS MATERIAL

Greer, South Carolina

Figure 3-3. On following page. **Lead** concentrations in soil litter in wooded area in the King Acres Subdivision adjacent to the Exide facility in mg/kg. Map after Webb (1997).

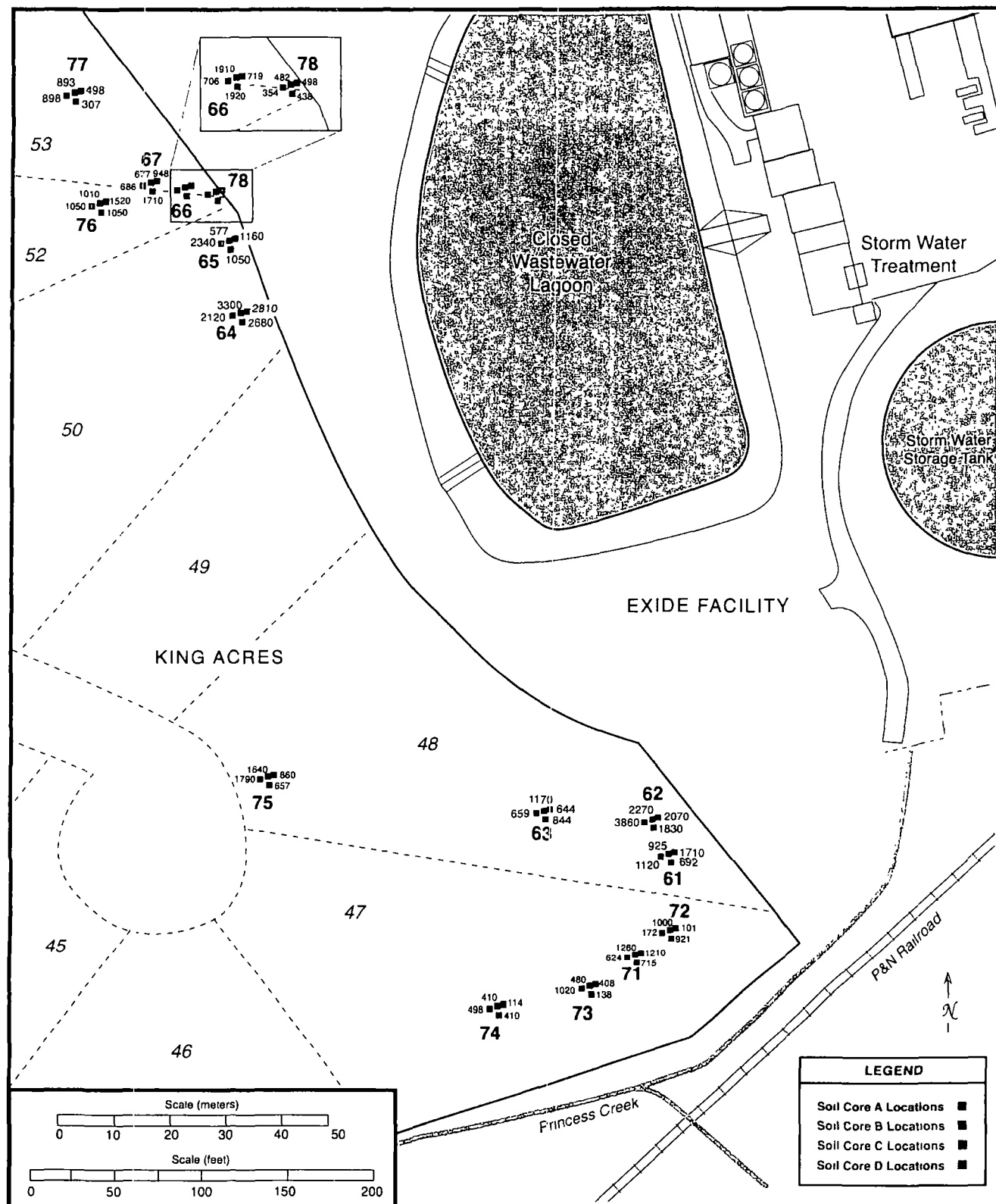


Figure 3-3  
LEAD CONCENTRATIONS IN SOIL  
LITTER IN WOODED AREA (mg/kg)  
King Acres Subdivision  
Greer, South Carolina

Figure 3-4. On following page. **Lead** concentrations in soil litter in wooded areas along railroad tracks adjacent to the Exide facility and the Westgate Trailer Park in mg/kg. Map after Webb (1997).

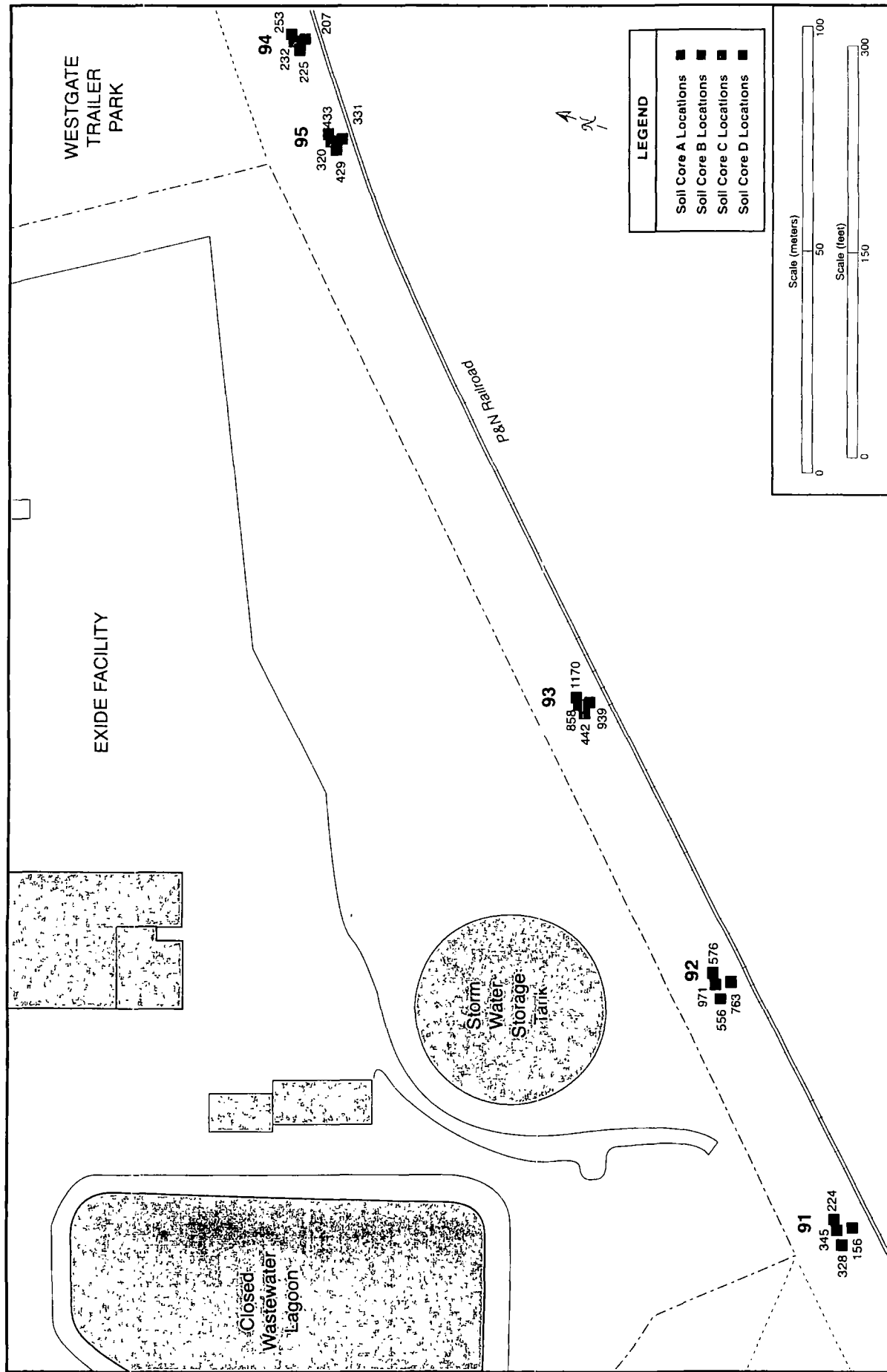


Figure 3-4  
 LEAD CONCENTRATIONS IN SOIL LITTER  
 IN WOODED AREA ALONG RAILROAD (mg/kg)  
 Greer, South Carolina

Figure 3-5. On following page. **Lead** concentrations in soil litter along Highway 101 in mg/kg.

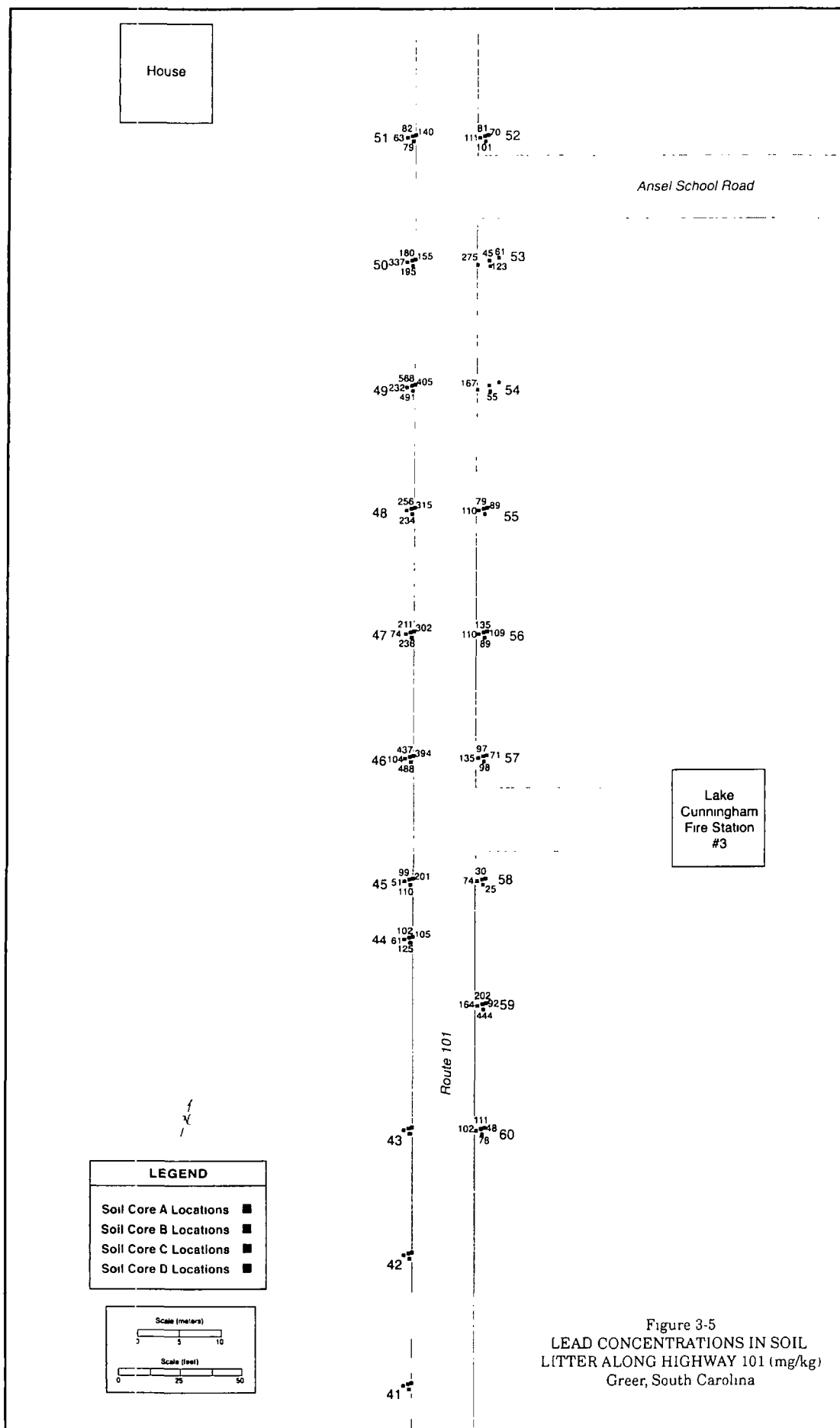




Figure 3-6a. On following page. Typical lead rich particle containing antimony, tin, and a trace of copper (particle class 10) from Exide soil litter. Red line = EDS response from particle labeled (1) in images (particle 35C1.1.2.1). Blue line = EDS response from material in full field of view. The blue line response indicated the presence of aluminum, iron, potassium, and silicon in material surrounding the lead rich particle. The presence of these elements in surrounding material typically interfered with their detection in lead bearing particles. FS = full scale of y-axis in counts (1474 counts). KeV = kilo-electron volts.

X-ray Display 1

— Class 10 Lead Particle - Exide Soil Litter (35C1.1.2.1)  
— Field of View

1474 FS

Si

Al

Pb

Sb

Cu

Fe

Fe

Cu

Pb

0.0

5.0

10.0

15.0

20.0

keV

Image Display 1



1 micrometer

Secondary Electron Image



1 micrometer

Backscatter Electron Image

Figure 3-6b. On following page. Typical lead rich particle containing phosphorous and a trace of copper (particle class 21) from Exide soil litter. Red line = EDS response from particle labeled (1) in images (particle 34B1.1.14.1). Blue line = EDS response from material in full field of view. The blue line response indicated the presence of aluminum, iron, potassium, silicon, and titanium in material surrounding the lead rich particle. The presence of these elements in surrounding material typically interfered with their detection in lead bearing particles. Calcium was also commonly present in the material surrounding many lead bearing particles. FS = full scale of y-axis in counts (2669 counts). KeV = kilo-electron volts.

X-ray Display 1

— Class 21 Lead Particle - Exide Soil Litter (34B1.1.14.1) 2669 FS  
— Field of View

Image Display 1



Backscatter Electron Image

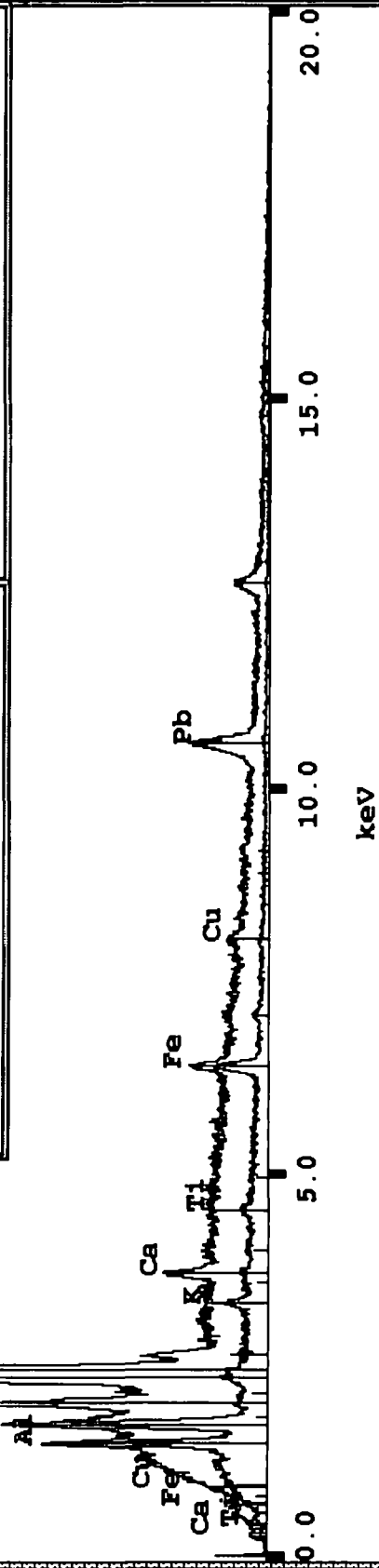


Figure 3-6c. On following page. Typical copper rich particle containing zinc and lead (particle class 80) from the roadside soil litter. Red line = EDS response from particle labeled (1) in images (particle 44B1 1.4.1). Blue line = EDS response from material in full field of view. The blue line response indicated the presence of aluminum, iron, and silicon in material surrounding the lead rich particle. The presence of these elements in surrounding material typically interfered with their detection in lead bearing particles. FS = full scale of y-axis in counts (1857 counts). KeV = kilo-electron volts.

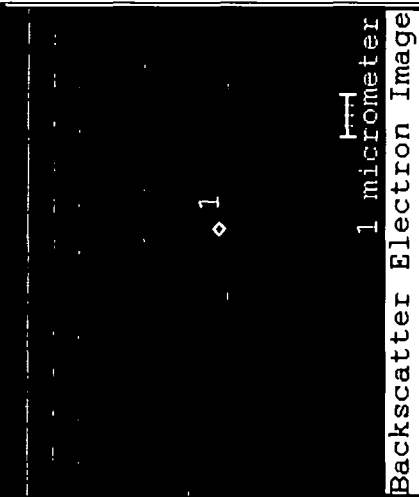
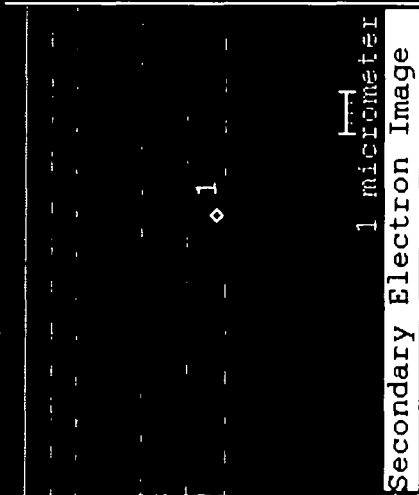
X-ray Display 1

— Class 80 Lead Particle - Roadside Soil Litter (44B1.1.4.1)  
— Field of View

1857 FS

Cu

Image-Display-1



Cu

Pb

Zn

Al

Si

Fe

Pb

Zn

5.0

10.0

15.0

20.0

keV

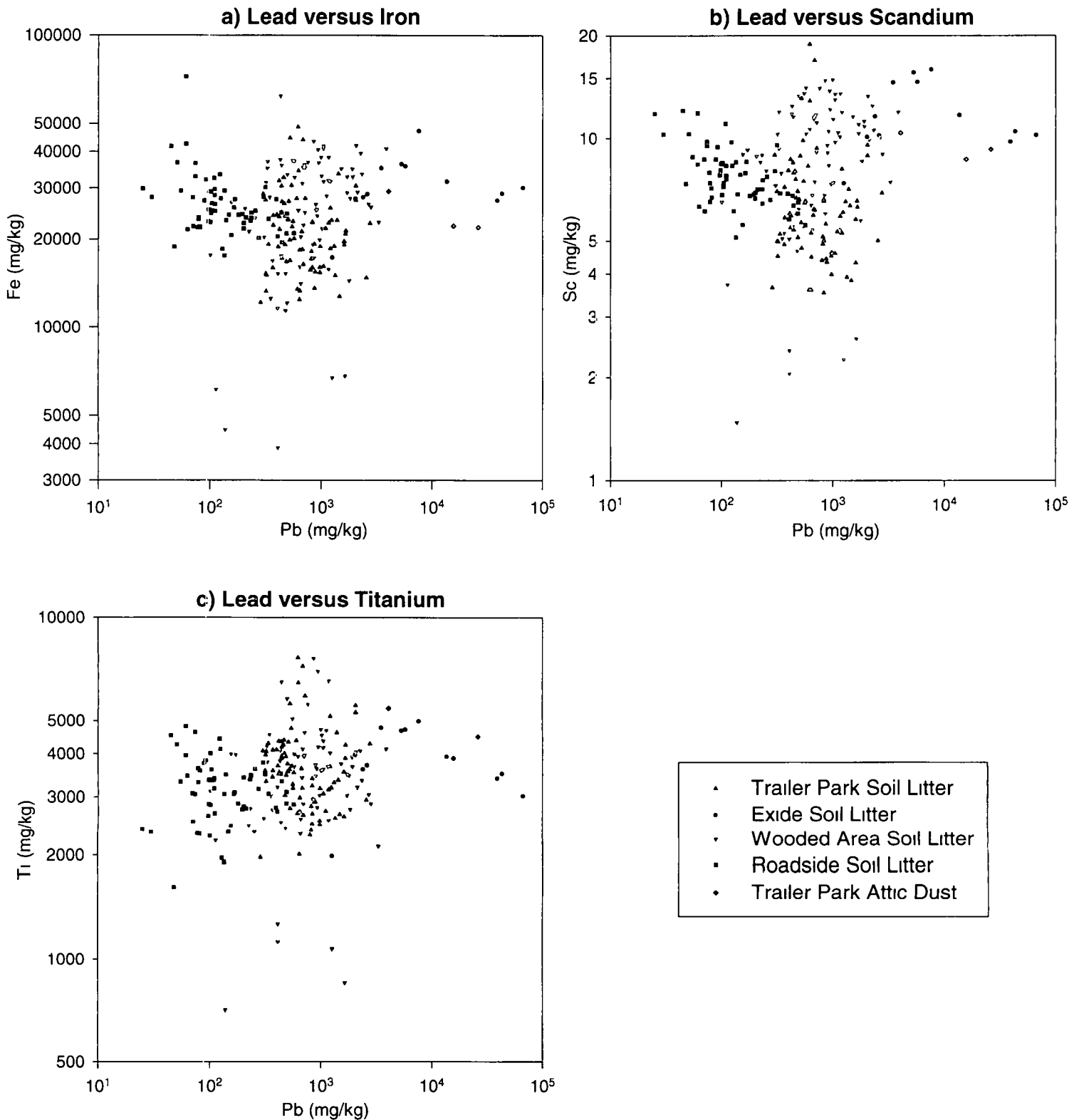


Figure 4-1. Scatter plots of **lead** concentrations versus: **a)** iron concentrations, **b)** scandium concentrations, and **c)** titanium concentrations in trailer park, Exide, wooded area, and roadside soil litter, and in trailer park attic dust. Concentrations are in mg/kg

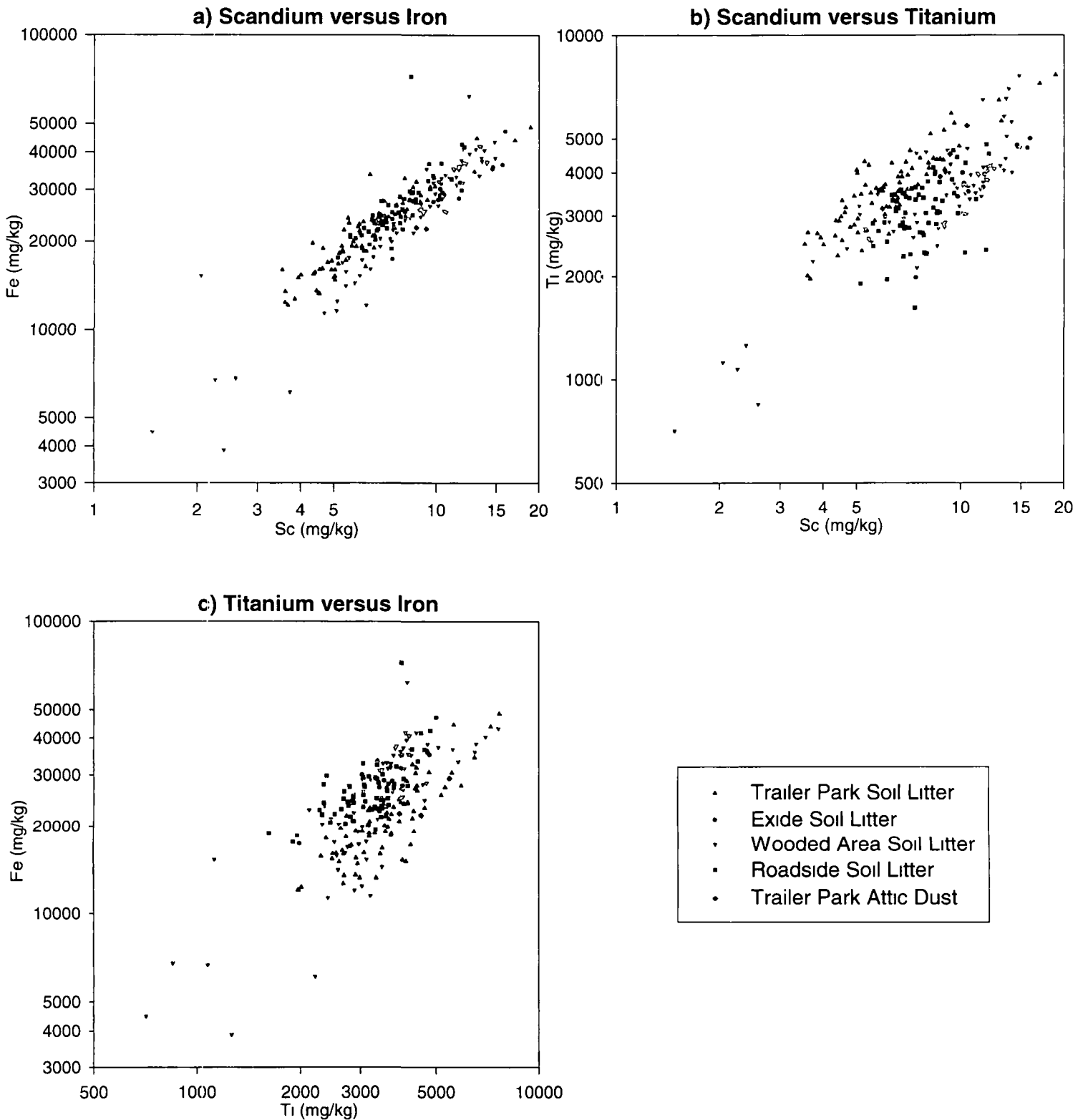


Figure 4-2 Scatter plots of: **a)** scandium concentrations versus iron concentrations, **b)** scandium concentrations versus titanium concentrations, and **c)** titanium concentrations versus iron concentrations in trailer park, Exide, wooded area, and roadside soil litter; and in trailer park attic dust. Concentrations are in mg/kg



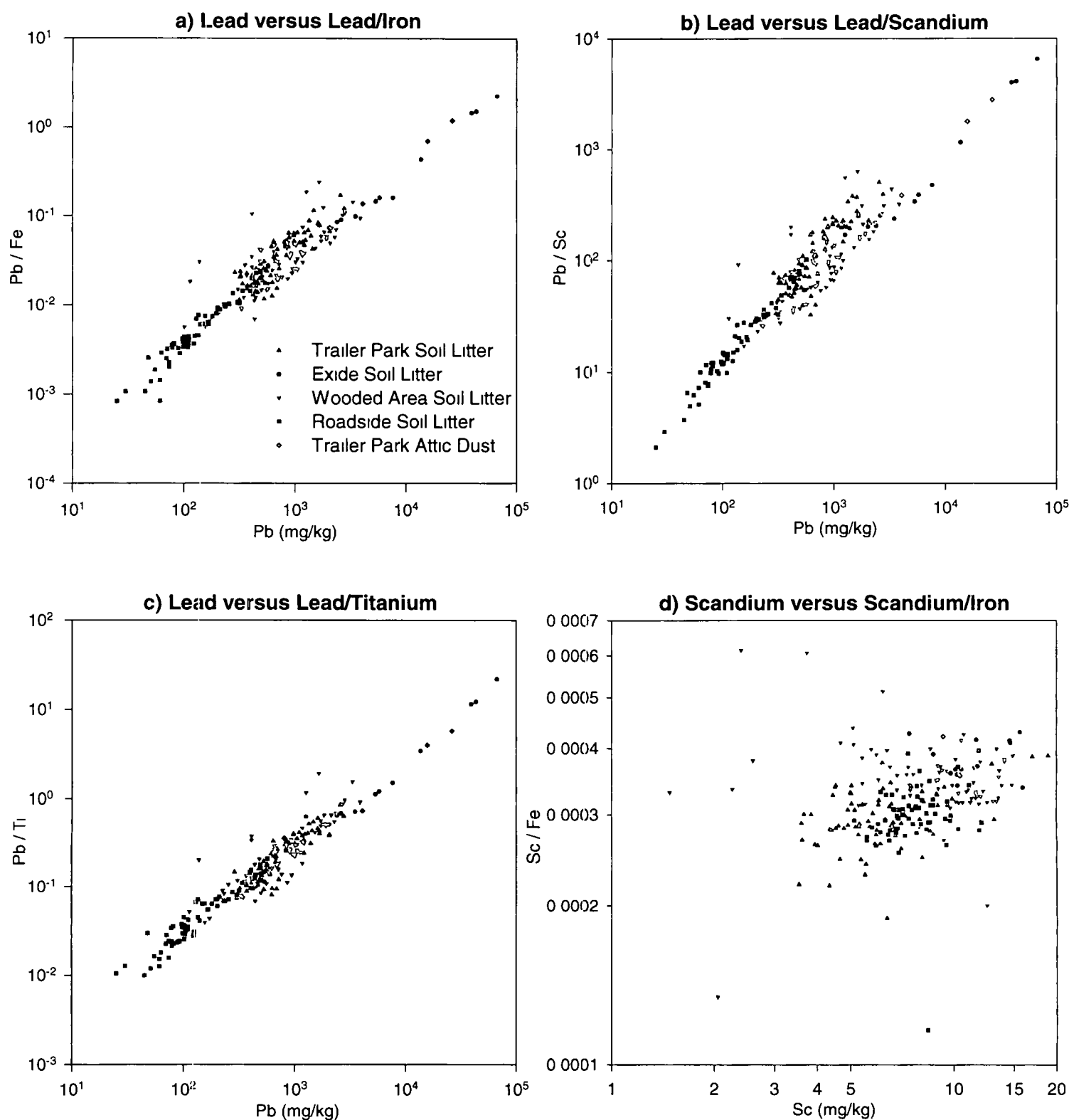


Figure 4-3. Scatter plots of **a) lead** concentrations versus the concentration ratios of lead/iron, **b) lead** concentrations versus the concentration ratios of lead/scandium, **c) lead** concentrations versus the concentration ratios of lead/titanium, and **d) scandium** concentrations versus the concentration ratios of scandium/iron in trailer park, Exide, wooded area, and roadside soil litter, and in trailer park attic dust. Concentrations are in mg/kg.

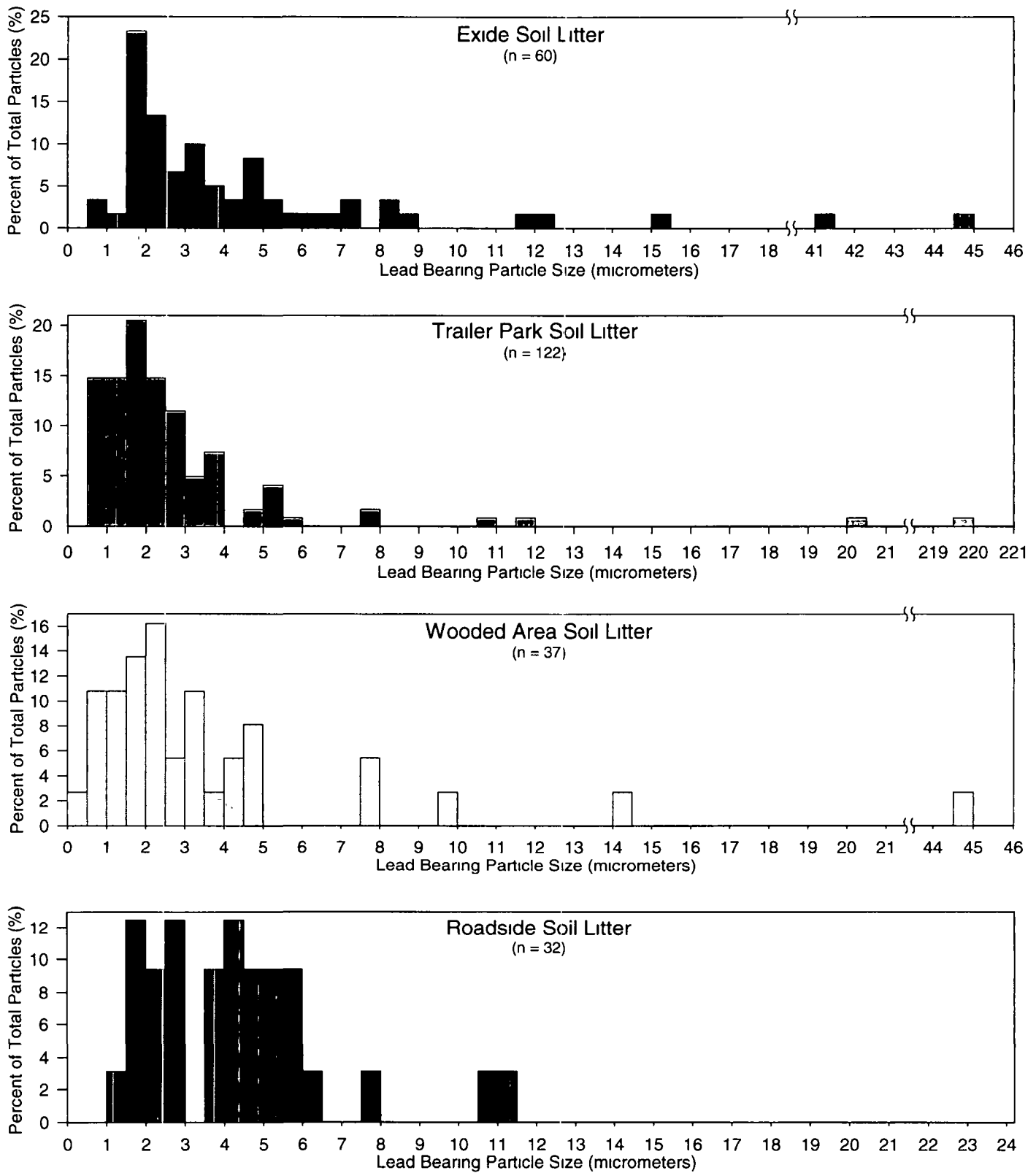


Figure 4-4 Histograms of particle size in micrometers for **lead** bearing particles in Exide, trailer park, wooded area, and roadside soil litter. n = number of lead bearing particles analyzed. Data are summarized in Table 3-10.

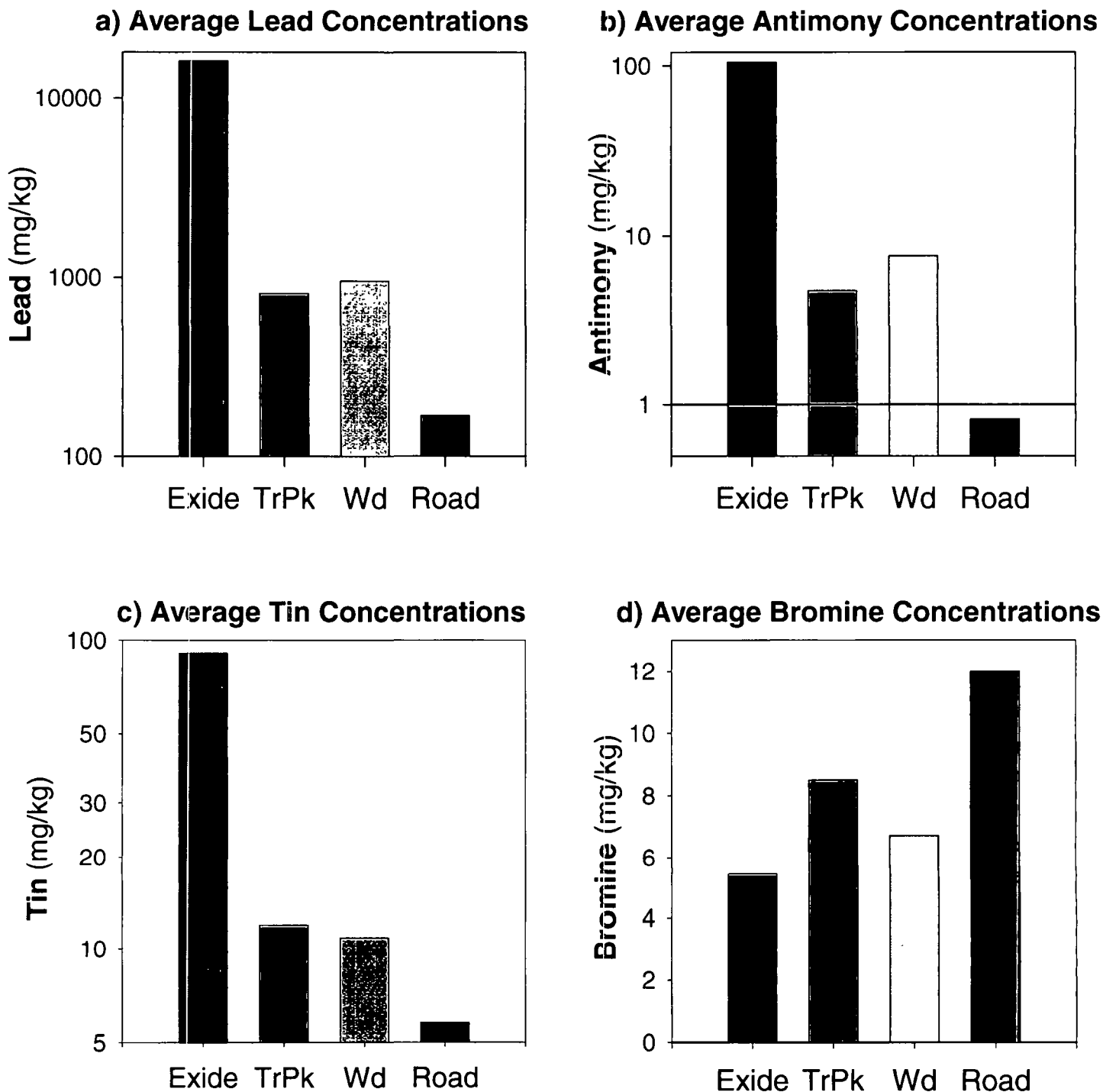


Figure 4-5. Bar charts of the average. a) **lead**, b) antimony, c) tin, and d) bromine concentrations in the soil litter of the Exide facility (Exide), Westgate Trailer Park (TrPk), adjacent wooded areas (Wd), and roadside (Road) Concentrations are given in mg/kg and also in Table 3-2.

# Lead versus Antimony

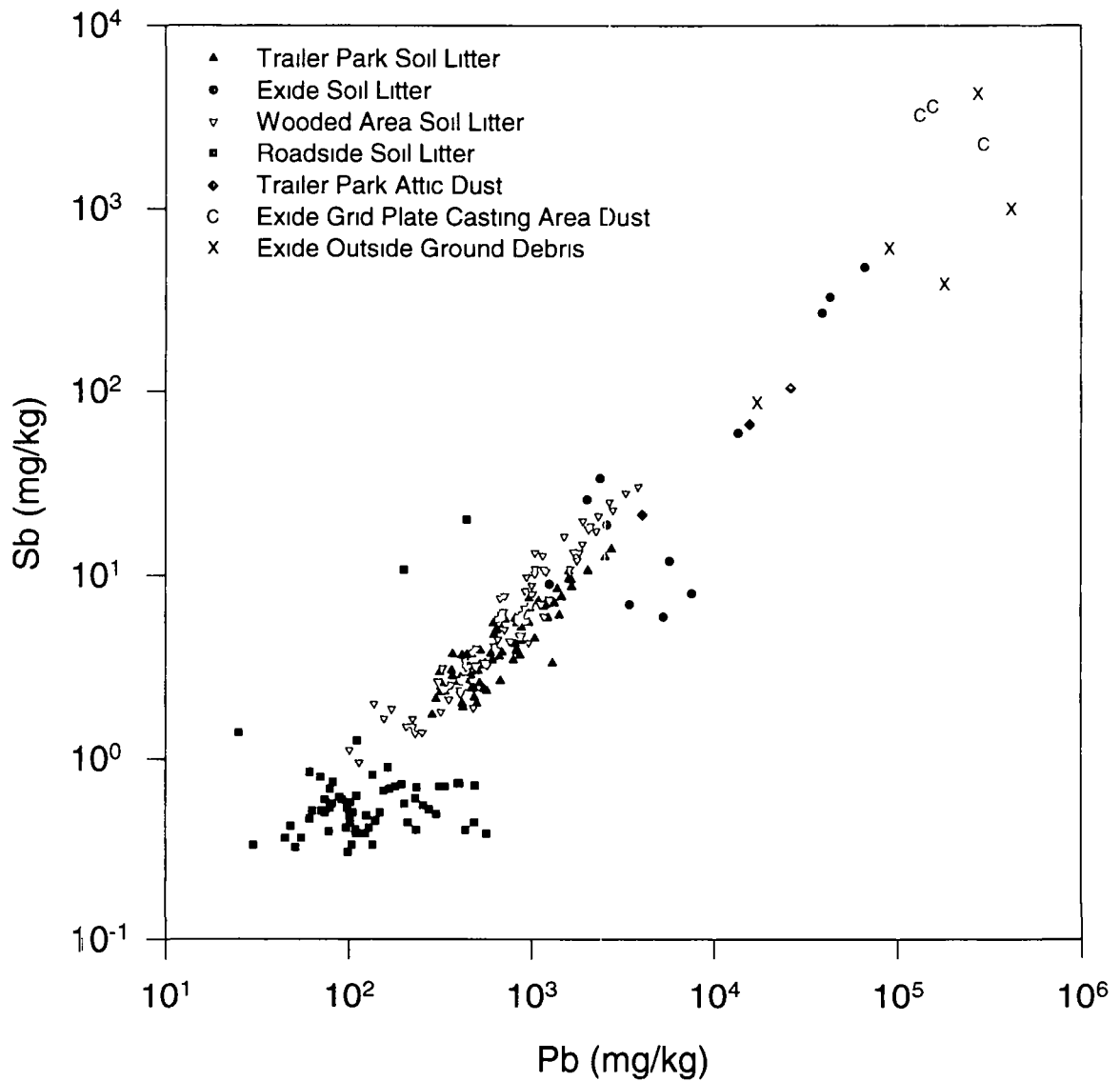


Figure 4-6. Scatter plot of **lead** concentration versus antimony concentration in trailer park, Exide, wooded area, and roadside soil litter; trailer park attic dust; and grid plate casting area dust and ground debris from the Exide facility. Concentrations are in mg/kg

# Lead versus Tin

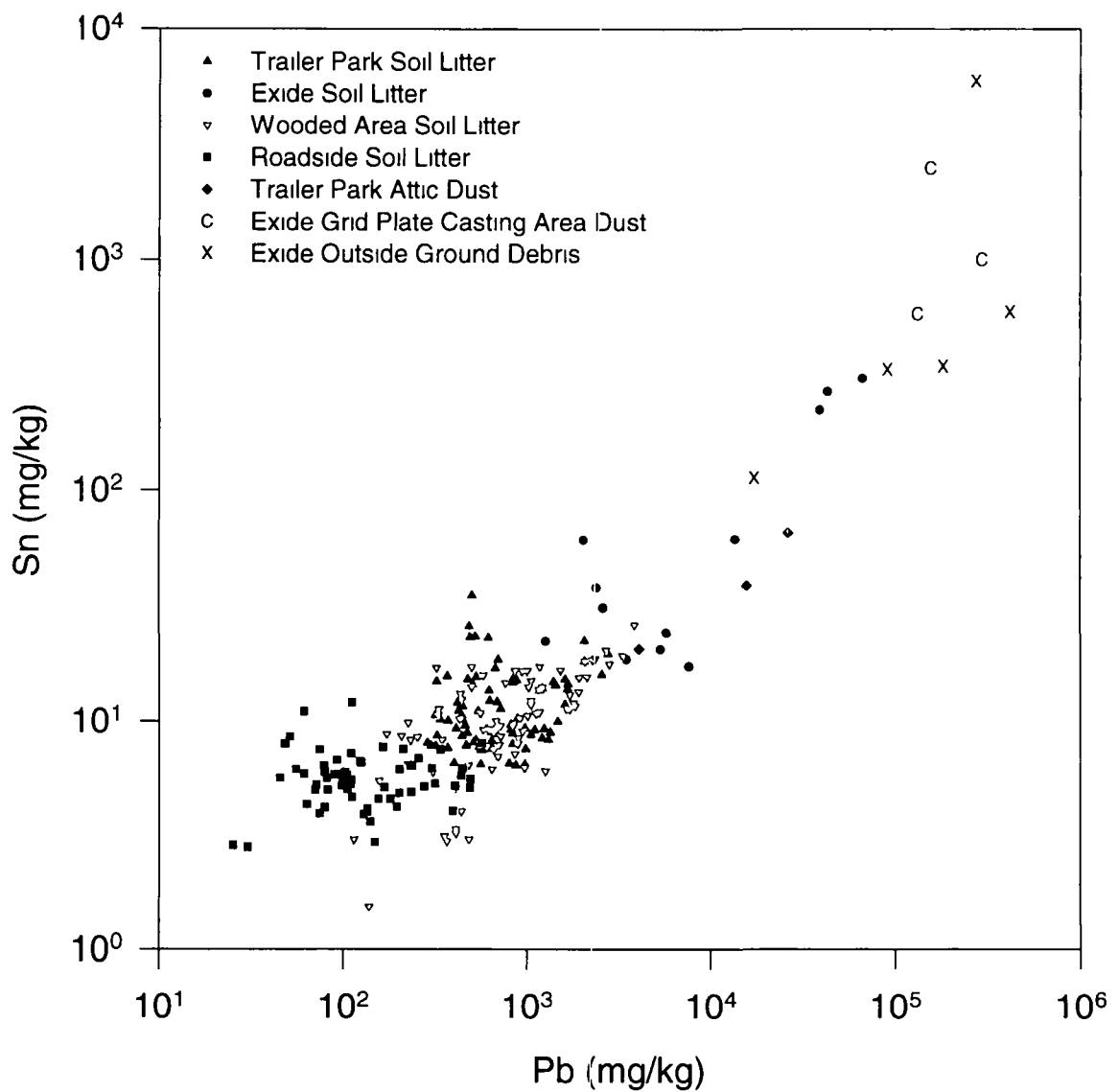


Figure 4-7 Scatter plot of **lead** concentration versus tin concentration in trailer park, Exide, wooded area, and roadside soil litter; trailer park attic dust, and grid plate casting area dust and ground debris from the Exide facility. Concentrations are in mg/kg.

# Lead versus Bromine

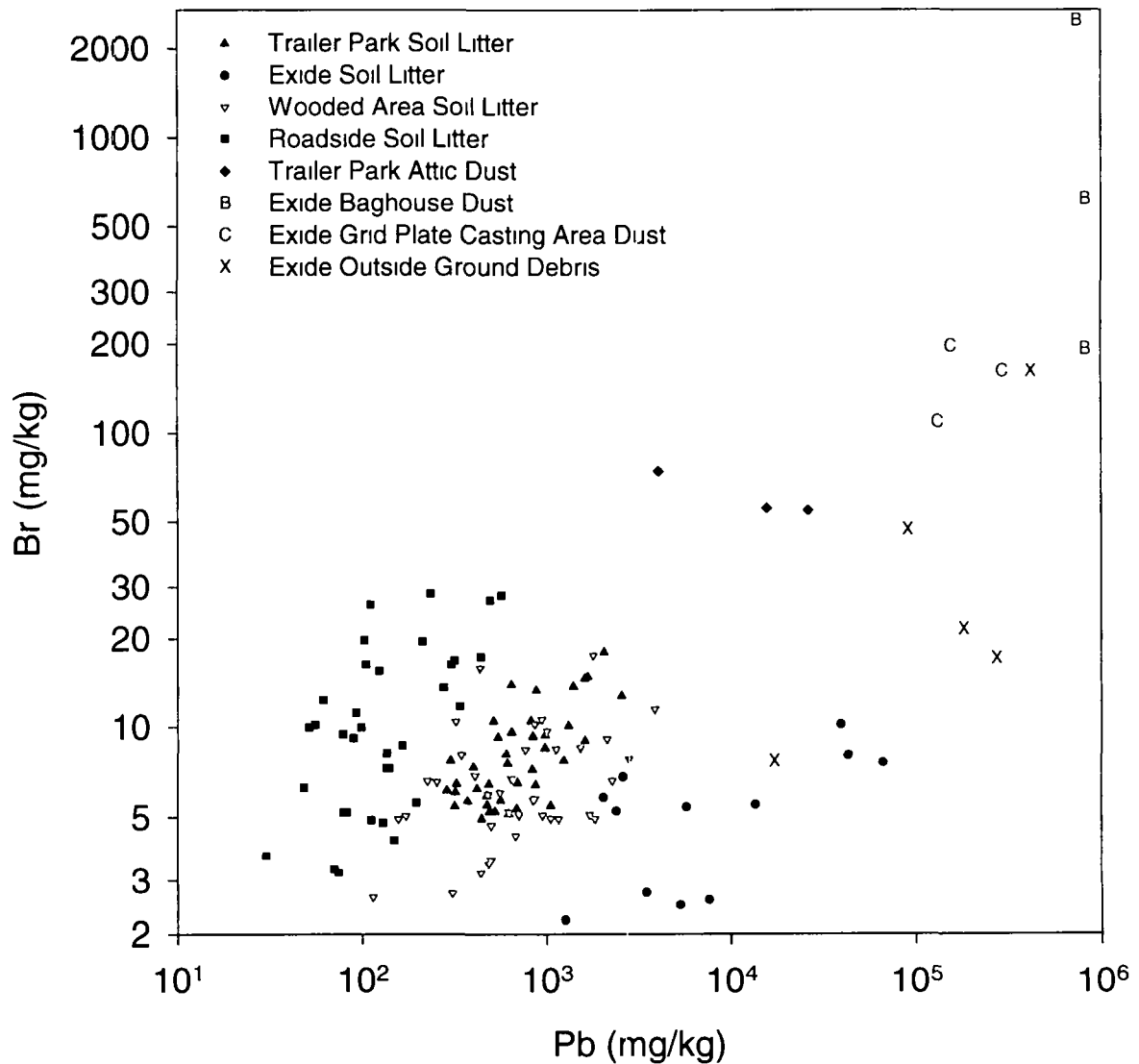


Figure 4-8 Scatter plot of **lead** concentration versus bromine concentration in trailer park, Exide, wooded area, and roadside soil litter; trailer park attic dust, and baghouse dust, grid plate casting area dust, and ground debris from the Exide facility. Concentrations are in mg/kg.

## Lead versus Lead/Antimony

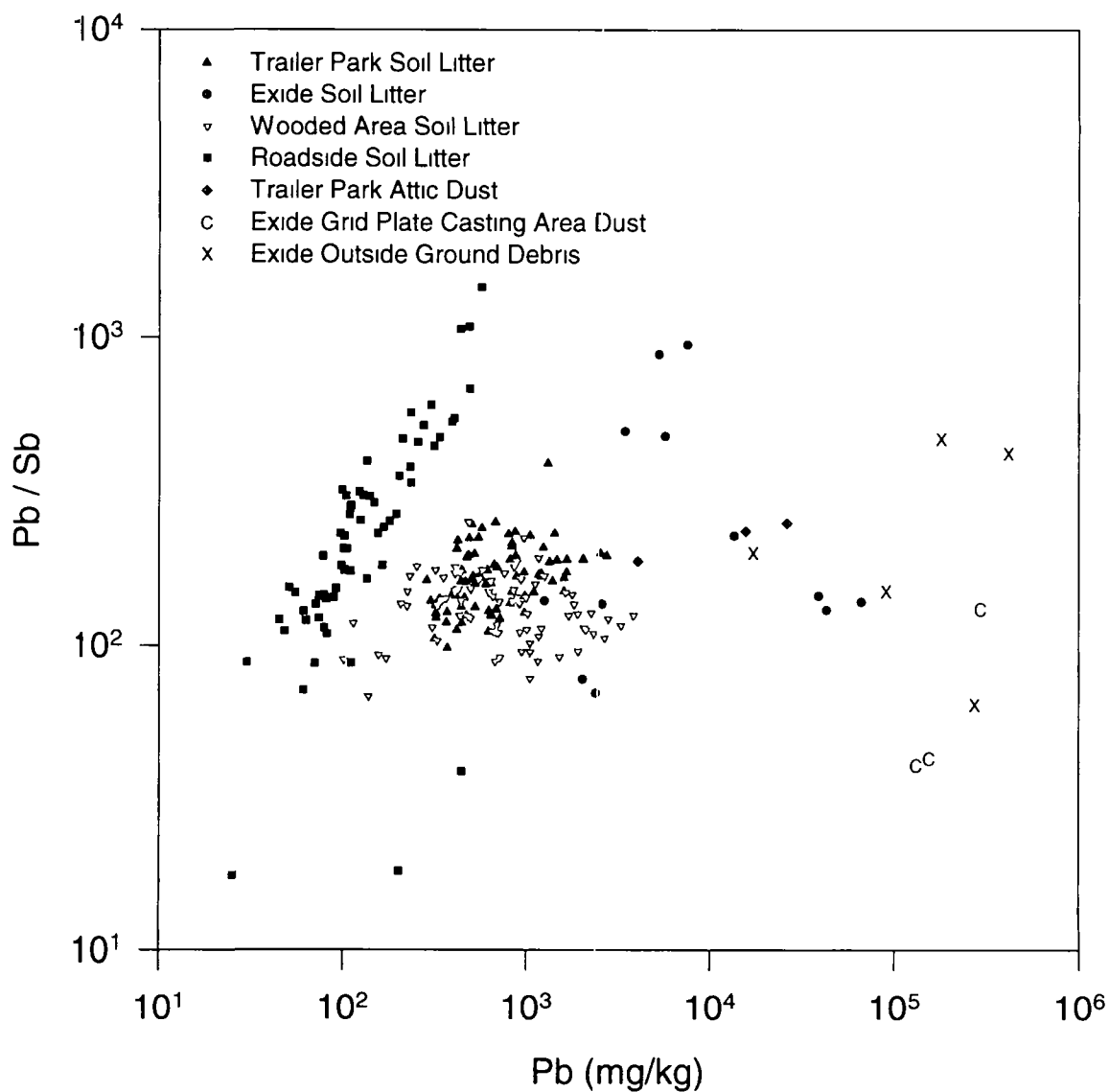


Figure 4-9 Scatter plot of **lead** concentration versus the concentration ratio of lead/antimony in trailer park, Exide, wooded area, and roadside soil litter, trailer park attic dust, and grid plate casting area dust and ground debris from the Exide facility. Concentrations are in mg/kg.

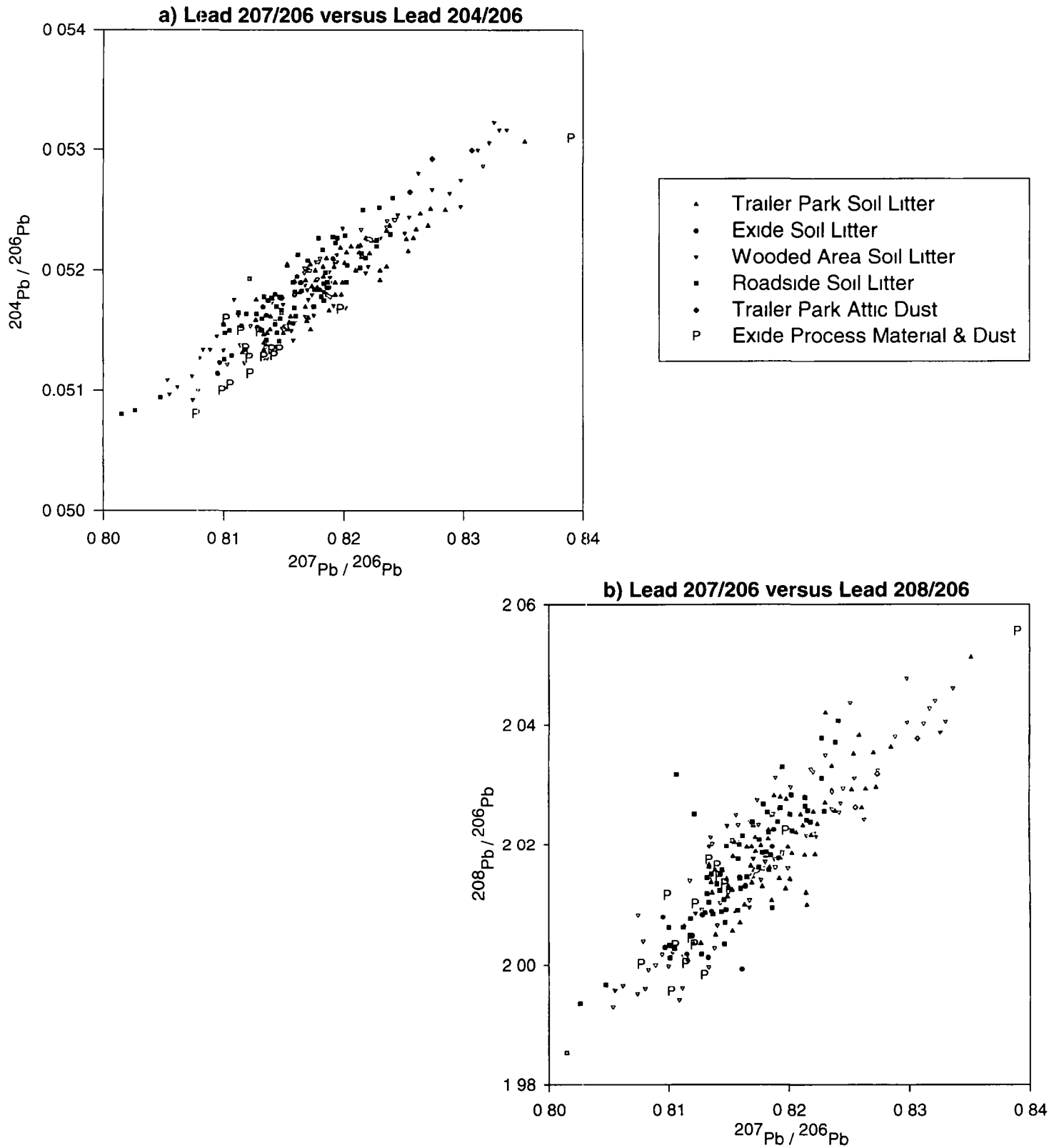


Figure 4-10 Scatter plot of: **a)** lead isotope ratio 207/206 versus lead isotope ratio 204/206 and **b)** lead isotope ratio 207/206 versus lead isotope ratio 208/206 in trailer park, Exide, wooded area, and roadside soil litter, trailer park attic dust; and Exide process materials and dust.



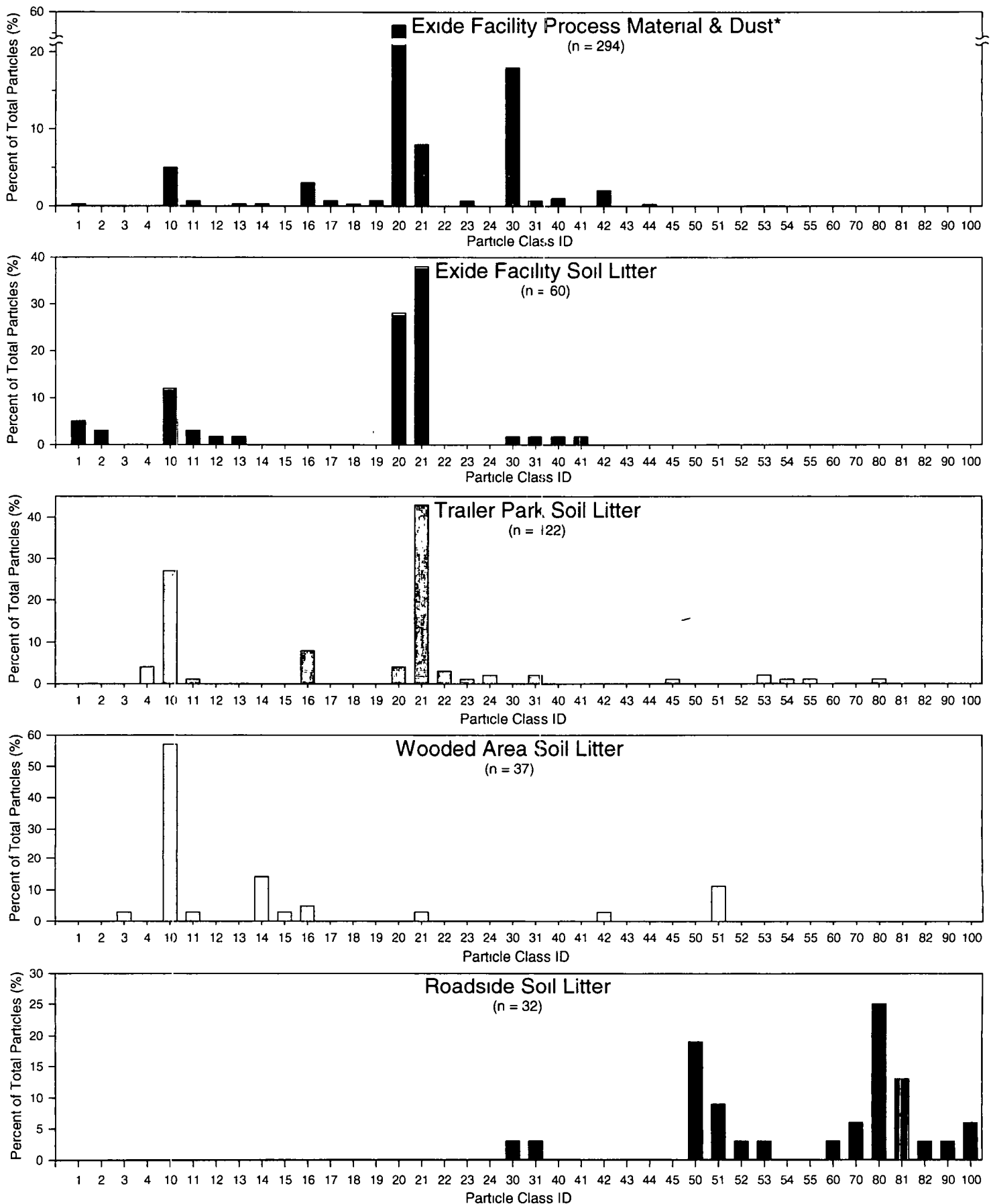


Figure 4-11. Bar charts of the percent of total **lead** bearing particles in **lead** bearing particle classes in Exide, trailer park, wooded area, and roadside soil litter; as well as in Exide process materials and dust. These data also appear in Table 3-8. \*Selection for analysis of lead bearing particles from Exide process materials and dust samples was generally limited to particles less than 10 to 20 micrometers in size. n = number of lead bearing particles analyzed.

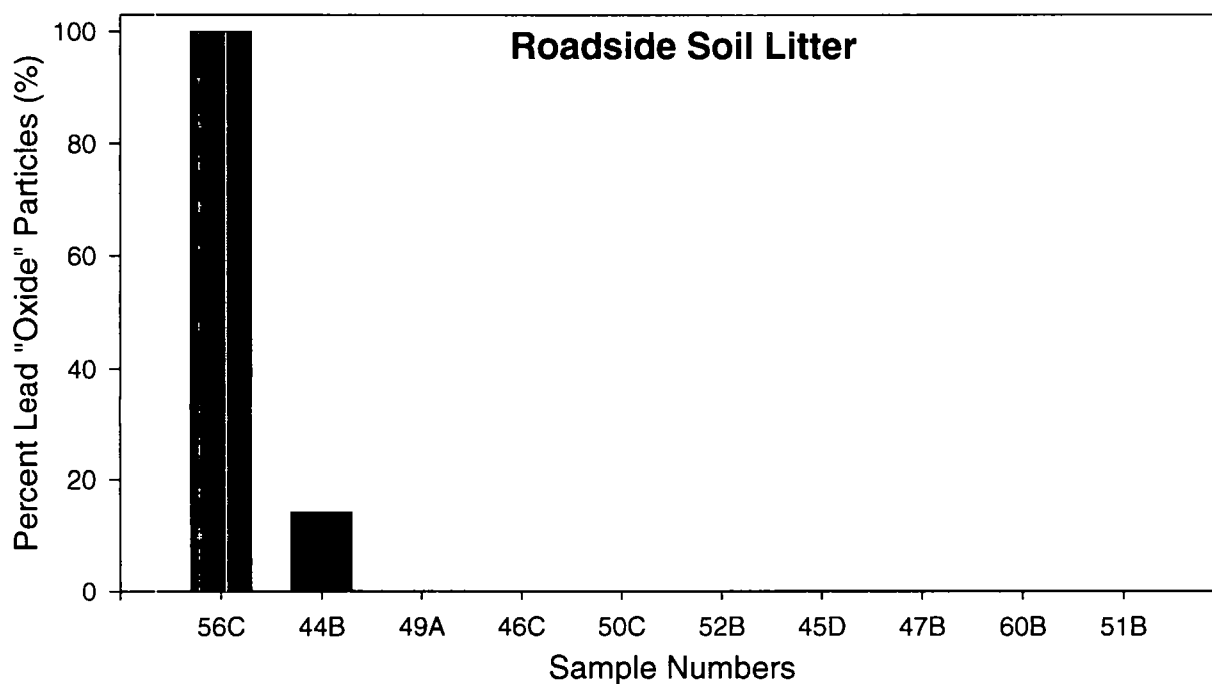
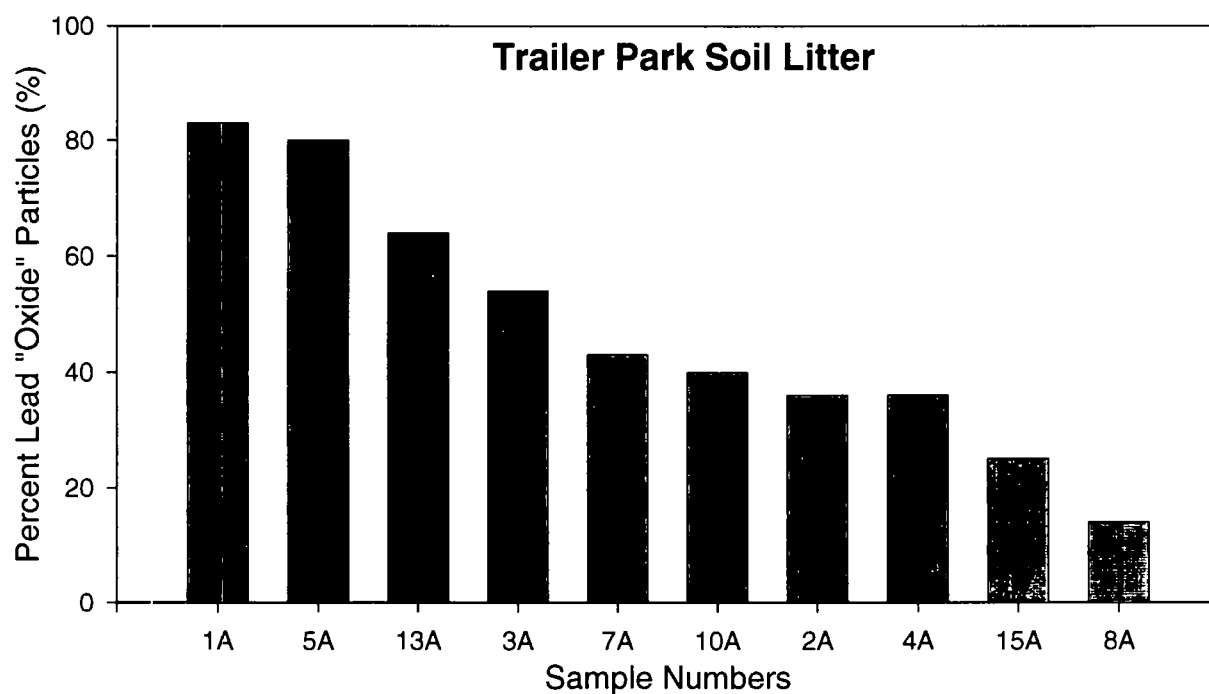


Figure 4-12. Bar charts of the percent of lead "oxide" particles (particle classes 20-24, 30, 31) relative to total lead bearing particles found in each of 10 soil litter samples from the trailer park and 10 soil litter samples from the roadside. Total lead "oxide" particles in trailer park soil litter out of 122 lead bearing particles = 66 (54%) Total lead "oxide" particles in roadside soil litter out of 32 lead bearing particles = 2 (6.3%).

**TABLES**

**ENFORCEMENT CONFIDENTIAL**

Table 2-1a. Locations of soil core "A" for each set of four soil cores collected in the Westgate Trailer Park on May 12, 1997. For locations of soil cores "B", "C", and "D" relative to soil core "A" for each set of soil cores, see Figure 2-1.

Sample	Fixed Point of Origin	Bearing	Distance meters (ft, in)	Template Dimension
01A	south corner of trailer 36	180°	2 36 (7' 9")	half dimension
02A	north corner of trailer 36	50°	2.57 (8' 5")	full dimension
03A	south corner of trailer 37	260°	3.66 (12' 0")	full dimension
04A	north corner of trailer 39	60°	6 50 (21' 4")	full dimension
05A	west corner of trailer 39	248°	3 81 (12' 6")	half dimension
06A	west corner of trailer 41	280°	5 23 (17' 2")	full dimension
07A	south corner of trailer 42	200°	4.27 (14' 0")	full dimension
08A	north corner of trailer 43	5°	2.44 (8' 0")	full dimension
09A	north corner of trailer 45	330°	2 67 (8' 9")	full dimension
10A	west corner of trailer 11	53°	3 67 (12' 0")	full dimension
11A	west corner of trailer 22	276°	5.94 (19' 6")	full dimension
12A	north corner of trailer 38	50°	5.64 (18' 6")	full dimension
13A	south corner of fence around house	210°	0 91 (3' 0")	full dimension
14A	south corner of trailer 46	262°	3.67 (12' 0")	half dimension
15A	south corner of trailer 48	270°	3 96 (13' 0")	half dimension
16A	west corner of trailer 50	298°	4 88 (16' 0")	full dimension
17A	south corner of trailer 27	90°	0 61 (2' 0")	full dimension
18A	south corner of trailer 25	200°	4.17 (13' 8")	full dimension
19A	north corner of trailer 13	60°	4 42 (14' 6")	full dimension
20A	north corner of trailer 21	30°	3 51 (11' 6")	full dimension

Table 2-1b. Collection locations of samples of attic dust collected from the house in the Westgate Trailer Park on May 14, 1997.

Sample	Sample Collection Location in the Attic of the House in the Trailer Park
96	north half of west wall and northwest side of attic in house in Westgate Trailer Park
97	south half of west wall and southwest side of attic in house in Westgate Trailer Park
98	east wall and east side of attic in house in Westgate Trailer Park

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Table 2-2a. Locations of soil core "A" for each set of four soil cores collected at the Exide facility in Greer, S.C. on May 13, 1997. For locations of soil cores "B", "C", and "D" relative to soil core "A" for each set of soil cores, see Figure 2-1.

Soil Core "A"	Fixed Point of Origin	Bearing	Distance meters (ft, in)	Template Dimension
33A	north corner of Exide building (red brick corner)	90°	2.18 (7' 2")	full dimension
34A	north corner of Exide building (red brick corner)	320°	7.82 (25' 8")	full dimension
35A	north corner of Exide building (white brick corner)	55°	3.73 (12' 3")	full dimension

Table 2-2b. Collection locations of soil cores and samples of process materials and dust collected at the Greer Exide facility on May 12 and 13, 1997.

Sample	Sample Collection Location at the Exide Facility
21	material from vent in pasting area
22	material from lead oxide pots
23	material from floor gratings in lead oxide area
24	material from lead oxide pile
25	dust from east wall between 3rd and 4th panel in old grid plate casting area (Omni area)
26	dust from south wall in old grid plate casting area (Omni area)
27	dust from north wall in old grid plate casting area (Omni area)
28	material from floor on north side of pasting mezzanine
29	material from exhaust vents in pasting mezzanine
30	material from floor near east wall of pasting area
31	material from Baghouse Dust Discharge Area 2 - Bin 2B
32	material from Baghouse Dust Discharge Area 2 - Bin 2A
33	4 soil cores - 33A through 33D - see Table 2-2a and Figure 2-3 for locations
34	4 soil cores - 34A through 34D - see Table 2-2a and Figure 2-3 for locations
35	4 soil cores - 35A through 35D - see Table 2-2a and Figure 2-3 for locations
36	ground debris material from location near outside door in north wall of old grid plate casting area (Omni area)
37	ground debris material from location near north outside door in east wall of old grid plate casting area (Omni area)
38	ground debris material from location in middle of asphalt area south of plant building (site previously marked EB-17)
39	ground debris material from location southwest of garage door for lead oxide area (site previously marked EB-15)
40	ground debris material from location north of transformer on south side of assembly area (site previously marked EB-14)
90	material from Baghouse Dust Discharge 4A outside assembly area

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Table 2-3. Analytical and dissolution techniques used for determining bulk chemical composition and lead isotope ratios. ICP = inductively coupled plasma, OES = optical emission spectroscopy, Hyd Gen = hydride generation, MS = mass spectrometry, KOH = potassium hydroxide fusion, HNO<sub>3</sub> = nitric acid digestion, HCl = hydrochloric acid digestion, INAA = instrumental neutron activation analysis.

Sample Area	Sample Material	Analytical Technique	Dissolution Technique	Analytes
Trailer Park	Soil Litter	ICP-OES	KOH	*
Trailer Park	Mineral Soil	ICP-OES	KOH	*
Trailer Park	Attic Dust	ICP-OES	KOH	*
Wooded Area	Soil Litter	ICP-OES	KOH	*
Roadside	Soil Litter	ICP-OES	KOH	*
Exide Facility	Soil Litter	ICP-OES	KOH	*
Exide Facility	Process Material & Dust	ICP-OES	KOH	*
Trailer Park	Soil Litter	Hyd Gen / ICP-OES	KOH	As
Trailer Park	Soil Litter	ICP-MS	HNO <sub>3</sub>	Cd, Pb <sup>1</sup>
Trailer Park	Soil Litter	ICP-MS	HCl	Sb <sup>2</sup>
Trailer Park	Attic Dust	ICP-MS	HCl	Sb, Pb <sup>1</sup> , Ag
Wooded Area	Soil Litter	ICP-MS	HCl	Sb, Pb <sup>1</sup> , Ag
Roadside	Soil Litter	ICP-MS	HCl	Sb, Pb <sup>1</sup>
Exide Facility	Soil Litter	ICP-MS	HCl	Sb, Pb <sup>1</sup>
Exide Facility	Process Material & Dust	ICP-MS	HCl	Sb, Pb <sup>1</sup>
Trailer Park	Soil Litter	Hyd Gen / ICP-MS	KOH	Sn <sup>3</sup>
Trailer Park	Attic Dust	Hyd Gen / ICP-MS	KOH	Sn
Wooded Area	Soil Litter	Hyd Gen / ICP-MS	KOH	Sn
Roadside	Soil Litter	Hyd Gen / ICP-MS	KOH	Sn
Exide Facility	Soil Litter	Hyd Gen / ICP-MS	KOH	Sn <sup>1</sup>
Exide Facility	Process Material & Dust	Hyd Gen / ICP-MS	KOH	Sn <sup>1</sup>
Trailer Park	Soil Litter	INAA	None	Br
Trailer Park	Attic Dust	INAA	None	Br
Wooded Area	Soil Litter	INAA	None	Br
Roadside	Soil Litter	INAA	None	Br
Exide Facility	Soil Litter	INAA	None	Br
Exide Facility	Process Material & Dust	INAA	None	Br
All Sample Areas	Soil Litter, Process Material, & Dust	ICP-MS	HCl	Pb isotope ratios

\*all elements reported except as otherwise noted in this table. <sup>1</sup>Confirmation by ICP-OES on KOH fusions. <sup>2</sup>Confirmation by Hyd Gen / ICP-OES on HCl digestions. <sup>3</sup>Confirmation by Hyd Gen / ICP-OES on KOH fusions.

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Table 3-1. **Lead** concentrations in the Westgate Trailer Park soil litter. ICP-MS results on HNO<sub>3</sub> digestions are in mg/kg dry weight. Std Dev = standard deviation, RSD = relative standard deviation, LCL = lower confidence limit, UCL = upper confidence limit.

Sample	Lead (mg/kg)	Sample Set Average (mg/kg)	Sample Set Std Dev (mg/kg)	RSD (%)	LCL of the Mean (mg/kg)	UCL of the Mean (mg/kg)
01A	983					
01B	1240					
01C	1210					
01D	973	1102	143	13	874	1329
02A	801					
02B	561					
02C	869					
02D	836	767	140	18	544	989
03A	559					
03B	1100					
03C	976					
03D	834	867	232	27	497	1237
04A	1430					
04B	642					
04C	1170					
04D	836	1020	350	34	463	1576
05A	1470					
05B	1610					
05C	1340					
05D	2550	1743	550	32	868	2617
06A	887					
06B	1050					
06C	645					
06D	819	850	168	20	583	1117
07A	620					
07B	625					
07C	686					
07D	718	662	48	7	586	738
08A	1210					
08B	2050					
08C	2050					
08D	1390	1675	439	26	976	2374
09A	2760					
09B	1610					
09C	1670					
09D	1660	1925	557	29	1038	2812
10A	572					
10B	602					
10C	1310					
10D	549	758	368	49	172	1344
11A	321					
11B	876					
11C	613					
11D	367	544	256	47	138	951

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Table 3-1. Continued...

Sample	Lead (mg/kg)	Sample Set Average (mg/kg)	Sample Set Std Dev (mg/kg)	RSD (%)	LCL of the Mean (mg/kg)	UCL of the Mean (mg/kg)
12A	679					
12B	641					
12C	526					
12D	817	666	120	18	475	857
13A	836					
13B	474					
13C	693					
13D	669	668	149	22	431	905
14A	418					
14B	371					
14C	445					
14D	316	388	57	15	297	478
15A	440					
15B	400					
15C	541					
15D	527	477	68	14	369	585
16A	466					
16B	512					
16C	301					
16D	460	435	92	21	288	581
17A	336					
17B	445					
17C	323					
17D	319	356	60	17	260	451
18A	442					
18B	370					
18C	471					
18D	411	424	43	10	355	492
19A	504					
19B	287					
19C	423					
19D	418	408	90	22	265	551
20A	502					
20B	485					
20C	488					
20D	522	499	17	3	472	526
<b>Average</b>	<b>812</b>	<b>812</b>	<b>197</b>	<b>22</b>	<b>498</b>	<b>1126</b>
<b>Minimum</b>	<b>287</b>	<b>356</b>	<b>17</b>	<b>3</b>	<b>138</b>	<b>451</b>
<b>Maximum</b>	<b>2760</b>	<b>1925</b>	<b>557</b>	<b>49</b>	<b>1038</b>	<b>2812</b>
<b>Std Dev</b>	<b>511</b>	<b>469</b>			<b>261</b>	<b>718</b>
<b>RSD (%)</b>	<b>63</b>	<b>58</b>			<b>52</b>	<b>64</b>
<b>Median</b>	<b>633</b>	<b>667</b>			<b>468</b>	<b>928</b>



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Table 3-2 Average (Avg) soil concentrations plus or minus ( $\pm$ ) one standard deviation (Std Dev) are given in mg/kg dry weight for antimony, **lead**, tin, and bromine in soil litter from the Exide facility, trailer park, wooded areas, and roadside. Relative standard deviations (RSD) are given in percent in parenthesis. Median soil concentrations are also given in mg/kg. n = number of data used in calculations of summary statistics for each data set, except as subscripted in parenthesis.

Element	Parameter	Exide Facility Soil Litter (n = 12)	Westgate Trailer Park Soil Litter (n = 80)	Wooded Areas Soil Litter (n = 80)	Roadside Soil Litter (n = 63)
Antimony (mg/kg)	Avg $\pm$ Std Dev RSD (%) Median	105 $\pm$ 161 (153%) 23	4.73 $\pm$ 2.66 (56%) 3.76	7.60 $\pm$ 6.72 (88%) 5.69 (n = 79)	0.82 $\pm$ 1.49 (182%) 0.53
Bromine (mg/kg)	Avg $\pm$ Std Dev RSD (%) Median	5.43 $\pm$ 2.57 (47%) 5.50 (n = 12)	8.50 $\pm$ 3.35 (39%) 7.53 (n = 40)	6.70 $\pm$ 3.42 (51%) 5.91 (n = 40)	12.0 $\pm$ 7.5 (63%) 10.0 (n = 34)
<b>Lead</b> (mg/kg)	Avg $\pm$ Std Dev RSD (%) Median	<b>16,100 <math>\pm</math>21,400</b> <b>(133%)</b> <b>5520</b>	<b>812 <math>\pm</math>511</b> <b>(63%)</b> <b>633</b>	<b>952 <math>\pm</math>755</b> <b>(79%)</b> <b>717</b>	<b>167 <math>\pm</math>127</b> <b>(76%)</b> <b>111</b>
Tin (mg/kg)	Avg $\pm$ Std Dev RSD (%) Median	91 $\pm$ 108 (119%) 34	12.0 $\pm$ 5.1 (43%) 10.2	10.9 $\pm$ 4.8 (44%) 10.3	5.8 $\pm$ 1.7 (29%) 5.7 (n = 62)

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Table 3-3a. Soil **lead** concentrations with depth in the Westgate Trailer Park. Lead concentrations by ICP-OES on potassium hydroxide fusions are in mg/kg dry weight. Averages are given plus or minus ( $\pm$ ) one standard deviation. Relative standard deviations (RSD) are given in percent in parenthesis.

Soil Core Number	02C	05D	08C	10C	16B	17A	19B	Average
Soil Litter (mg/kg)	820	2330	1960	1360	590	370	330	1110 $\pm$ 790 (71%)
Upper Mineral Soil (mg/kg)	320	1900	1980	930	240	430	380	880 $\pm$ 760 (86%)
Lower Mineral Soil (mg/kg)	180	420	1040	510	100	250	170	380 $\pm$ 320 (84%)

Table 3-3b. Soil layer depth intervals in soil cores collected in the Westgate Trailer Park. Depths are given in centimeters (cm) (1 inch = 2.54 cm). Average depth of the top of each soil layer is given in centimeters plus or minus ( $\pm$ ) one standard deviation and in inches in parenthesis.

Soil Core Number	02C	05D	08C	10C	16B	17A	19B	Average Depth of Soil Layer Top
Soil Litter cm	0 - 5.5	0 - 4.5	0 - 4.0	0 - 7.0	0 - 3.0	0 - 0.5	0 - 5.0	0
Upper Mineral Soil cm (inches)	5.5 - 8.0	4.5 - 7.0	4.0 - 6.5	7.0 - 9.5	3.0 - 5.5	0.5 - 3.0	5.0 - 7.5	4.2 $\pm$ 2.1 (1.7")
Lower Mineral Soil cm (inches)	8.0 - 15	7.0 - 15	6.5 - 15	9.5 - 15	5.5 - 15	3.0 - 15	7.5 - 15	6.7 $\pm$ 2.1 (2.6")

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Table 3-4. **Lead** concentrations in the soil litter at the Exide facility. ICP-MS results on HCl digestions are in mg/kg dry weight. Std Dev = standard deviation, RSD = relative standard deviation.

Sample	Lead (mg/kg)	Sample Set Average (mg/kg)	Sample Set Std Dev (mg/kg)	RSD (%)
33A	39100			
33B	13600			
33C	43100			
33D	66600	40600	21700	53
34A	5300			
34B	7590			
34C	3470			
34D	5730	5520	1690	31
35A	2390			
35B	2030			
35C	2600			
35D	1260	2070	589	28
<b>Average</b>	<b>16100</b>	<b>16100</b>	<b>7990</b>	<b>37</b>
<b>Minimum</b>	<b>1260</b>	<b>2070</b>	<b>589</b>	<b>28</b>
<b>Maximum</b>	<b>66600</b>	<b>40600</b>	<b>21700</b>	<b>53</b>
<b>Std Dev</b>	<b>21400</b>	<b>21300</b>		
<b>RSD (%)</b>	<b>133</b>	<b>133</b>		
<b>Median</b>	<b>5520</b>	<b>5520</b>		

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Table 3-5. **Lead**, antimony, and tin concentrations in process material and dust at the Exide facility in mg/kg. Lead and antimony results were by ICP-MS on HCl digestions. Tin results were by hydride generation coupled with ICP-MS on KOH fusions. Std Dev = standard deviation, RSD = relative standard deviation.

Sample	Location	Lead (mg/kg)	Sample Set			Antimony (mg/kg)	Tin (mg/kg)
			Lead Average (mg/kg)	Lead Std Dev (mg/kg)	Lead RSD (%)		
22	Lead Oxide Area	818000				231	355
23	Lead Oxide Area	784000				616	17
24	Lead Oxide Area	853000	818000	34500	4	< 7	56
25	Grid Plate Casting Area	132000				3240	584
26	Grid Plate Casting Area	294000				2250	999
27	Grid Plate Casting Area	155000	194000	87600	45	3620	2490
21	Pasting Area	808000				271	88
28	Pasting Area	816000				38	68
29	Pasting Area	694000				67	35
30	Pasting Area	848000	792000	67300	8	22	21
31	Baghouse	823000				544	716
32	Baghouse	821000				13	852
90	Baghouse	741000	795000	46800	6	1090	2210
36	Ground Outside Building	17200				87	113
37	Ground Outside Building	273000				4260	5920
38	Ground Outside Building	90500				607	335
39	Ground Outside Building	181000				389	345
40	Ground Outside Building	417000	196000	157000	80	1000	593

Table 3-6. **Lead** concentrations in the soil litter in the adjacent wooded areas. ICP-MS results on HCl digestions are in mg/kg dry weight. Std Dev = standard deviation, RSD = relative standard deviation.

Sample	Lead (mg/kg)	Sample Set Average (mg/kg)	Sample Set Std Dev (mg/kg)	RSD (%)
61A	925			
61B	1710			
61C	692			
61D	1120	1110	436	39
62A	2270			
62B	2070			
62C	1830			
62D	3860	2510	919	37
63A	1170			
63B	644			
63C	844			
63D	659	829	245	30
64A	3300			
64B	2810			
64C	2680			
64D	2120	2730	485	18
65A	577			
65B	1160			
65C	1050			
65D	2340	1280	749	58
66A	1910			
66B	719			
66C	1920			
66D	706	1310	694	53
67A	677			
67B	948			
67C	1710			
67D	686	1010	486	48
71A	1260			
71B	1210			
71C	715			
71D	624	952	329	35
72A	1000			
72B	101			
72C	921			
72D	172	548	478	87
73A	480			
73B	408			
73C	138			
73D	1020	512	370	72
74A	410			
74B	114			
74C	410			
74D	498	358	168	47

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Table 3-6. Continued...

Sample	Lead (mg/kg)	Sample Set Average (mg/kg)	Sample Set Std Dev (mg/kg)	RSD (%)
75A	1640			
75B	860			
75C	657			
75D	1790	1240	562	45
76A	1010			
76B	1520			
76C	1050			
76D	1050	1160	242	21
77A	893			
77B	498			
77C	307			
77D	898	649	295	45
78A	482			
78B	366			
78C	438			
78D	354	410	61	15
91A	345			
91B	224			
91C	156			
91D	328	263	89	34
92A	971			
92B	576			
92C	763			
92D	556	716	194	27
93A	858			
93B	1170			
93C	939			
93D	442	852	304	36
94A	232			
94B	253			
94C	207			
94D	225	229	19	8
95A	320			
95B	433			
95C	331			
95D	429	378	61	16
<b>Average</b>	<b>952</b>	<b>952</b>	<b>359</b>	<b>39</b>
<b>Minimum</b>	<b>101</b>	<b>229</b>	<b>19</b>	<b>8</b>
<b>Maximum</b>	<b>3860</b>	<b>2730</b>	<b>919</b>	<b>87</b>
<b>Std Dev</b>	<b>755</b>	<b>667</b>		
<b>RSD (%)</b>	<b>79</b>	<b>70</b>		
<b>Median</b>	<b>717</b>	<b>841</b>		

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Table 3-7. **Lead** concentrations in the roadside soil litter. ICP-MS results on HCl digestions are in mg/kg dry weight. Std Dev = standard deviation, RSD = relative standard deviation.

Sample	Lead (mg/kg)	Sample Set Average (mg/kg)	Sample Set Std Dev (mg/kg)	RSD (%)
44A	102			
44B	105			
44C	125			
44D	61	98	27	27
45A	99			
45B	201			
45C	110			
45D	51	115	63	54
46A	437			
46B	394			
46C	488			
46D	104	356	172	48
47A	211			
47B	302			
47C	236			
47D	74	206	96	47
48A	256			
48B	315			
48C	234	268	42	16
49A	568			
49B	405			
49C	491			
49D	232	424	144	34
50A	180			
50B	155			
50C	195			
50D	337	217	82	38
51A	82			
51B	140			
51C	79			
51D	63	91	34	37
52A	81			
52B	70			
52C	101			
52D	111	91	19	21

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Table 3-7. Continued...

Sample	Lead (mg/kg)	Sample Set Average (mg/kg)	Sample Set Std Dev (mg/kg)	RSD (%)
53A	45			
53B	61			
53C	123			
53D	275	126	105	83
54C	55			
54D	167	111	79	71
55A	79			
55B	89			
55D	110	93	16	17
56A	135			
56B	109			
56C	148			
56D	129	130	16	12
57A	97			
57B	71			
57C	98			
57D	135	100	26	26
58A	30			
58C	25			
58D	74	43	27	63
59A	202			
59B	92			
59C	444			
59D	164	313	324	103
60A	111			
60B	48			
60C	78			
60D	102	85	28	33
<b>Average</b>	<b>167</b>	<b>119</b>	<b>54</b>	<b>30</b>
<b>Minimum</b>	<b>25</b>	<b>43</b>	<b>16</b>	<b>12</b>
<b>Maximum</b>	<b>568</b>	<b>424</b>	<b>324</b>	<b>103</b>
<b>Std Dev</b>	<b>127</b>	<b>121</b>		
<b>RSD (%)</b>	<b>76</b>	<b>101</b>		
<b>Median</b>	<b>111</b>	<b>95</b>		



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Table 3-8. Summary of individual particle analysis data The number of **lead** bearing particles found in each particle class is given for each sample set with the percentage of total sample set particles in each class given in parenthesis. ID = particle class identifier. \*Selection for analysis of lead bearing particles from Exide process material and dust samples was generally limited to particles less than 10 to 20 micrometers in size. Most common particle classes appear in **bold** type.

Particle Class	ID	Exide Battery Facility			Trailer Park		Wooded Areas	Roadside
		Process Material and Dust*	Soil Litter	Air Filters	Soil Litter	Attic Dust	Soil Litter	Soil Litter
Sn-rich with Pb Cu	1	1 (0.3%)	3 (5%)					
Sn-rich with Pb	2		2 (3%)					
Sb-rich with Pb Sn Cu	3						1 (3%)	
Sn-rich with Pb Sb Cu	4				5 (4%)			
<b>Pb-rich with Sb Sn Cu</b>	<b>10</b>	<b>15 (5%)</b>	<b>7 (12%)</b>		<b>33 (27%)</b>		<b>21 (57%)</b>	
Pb-rich with Sb Cu	11	2 (0.7%)	2 (3%)		1 (1%)		1 (3%)	
Pb-rich with Sb P Cu	12		1 (1.7%)					
Pb-rich with Sn	13	1 (0.3%)	1 (1.7%)					
Pb-rich with Sb Sn	14	1 (0.3%)					5 (14%)	
Pb-rich with Sb P	15						1 (3%)	
<b>Pb-rich with Sb Sn P Cu</b>	<b>16</b>	<b>10 (3%)</b>			<b>10 (8%)</b>		<b>2 (5%)</b>	
Pb-rich with Sb Sn P Cu Zn	17	2 (0.7%)						
Pb-rich with Sb Sn Cu Zn	18	1 (0.3%)						
Pb-rich with Sn P Cu	19	2 (0.7%)						
<b>Pb-rich with Cu</b>	<b>20</b>	<b>167 (57%)</b>	<b>17 (28%)</b>	<b>4 (10%)</b>	<b>5 (4%)</b>	<b>29 (97%)</b>		
<b>Pb-rich with P Cu</b>	<b>21</b>	<b>23 (8%)</b>	<b>23 (38%)</b>	<b>1 (3%)</b>	<b>52 (43%)</b>	<b>1 (3%)</b>	<b>1 (3%)</b>	
Pb-rich with P Cu Zn	22				4 (3%)			
Pb-rich with Cu Zn	23	2 (0.7%)			1 (1%)			
Pb-rich with P Zn	24				2 (2%)			
Pb-rich	30	54 (18%)	1 (1.7%)	34 (85%)				1 (3%)
Pb-rich with P	31	2 (0.7%)	1 (1.7%)		2 (2%)			1 (3%)
Pb-rich with Ba Cu	40	4 (1%)	1 (1.7%)					
Pb-rich with Ba P Cu	41		1 (1.7%)					
Pb-rich with Ba	42	6 (2%)					1 (3%)	
Pb-rich with Ba Cl	43			1 (3%)				
Pb-rich with Sn Ba Cu	44	1 (0.3%)						
Pb-rich with Sb Sn P Cu Ba	45				1 (1%)			
Pb-rich with Mn	50							6 (19%)
Mn-rich with Pb	51						4 (11%)	3 (9%)
Mn-rich with Pb Cl	52							1 (3%)
Pb-rich with Cu Mn P Zn	53				3 (2%)			1 (3%)
Pb-rich with Mn P Cu	54				1 (1%)			
Pb-rich with Mn P	55				1 (1%)			
Pb-rich with Cl Cu	60							1 (3%)
Pb-rich with Cl	70							2 (6%)
<b>Cu-rich with Zn Pb</b>	<b>80</b>				<b>1 (1%)</b>			<b>8 (25%)</b>
<b>Cu-rich with Zn Pb Cl</b>	<b>81</b>							<b>4 (13%)</b>
Cu-rich with Zn Pb Cl Cr Ni P S	82							1 (3%)
Pb-rich with S	90							1 (3%)
Fe-rich with Pb	100							2 (6%)
<b>Total Particles Analyzed</b>		<b>294</b>	<b>60</b>	<b>40</b>	<b>122</b>	<b>30</b>	<b>37</b>	<b>32</b>

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Table 3-9. Average weight percent (%) of lead in particles of the lead particle classes found in the trailer park, wooded area, and roadside soil litter. Lead contents were determined as described in the Methods section. These average lead contents were used to calculate the apportionment of lead in the soil of these areas. ID = particle class identifier. Most common particle classes appear in **bold** type.

Particle Class	ID	Trailer Park Soil Litter	Wooded Areas Soil Litter	Roadside Soil Litter
Sn-rich with Pb Cu	1			
Sn-rich with Pb	2			
Sb-rich with Pb Sn Cu	3		26%	
Sn-rich with Pb Sb Cu	4	23%		
<b>Pb-rich with Sb Sn Cu</b>	<b>10</b>	<b>51%</b>	<b>54%</b>	
Pb-rich with Sb Cu	11	54%	55%	
Pb-rich with Sb P Cu	12			
Pb-rich with Sn	13			
Pb-rich with Sb Sn	14		53%	
Pb-rich with Sb P	15		57%	
<b>Pb-rich with Sb Sn P Cu</b>	<b>16</b>	<b>61%</b>	<b>53%</b>	
Pb-rich with Sb Sn P Cu Zn	17			
Pb-rich with Sb Sn Cu Zn	18			
Pb-rich with Sn P Cu	19			
<b>Pb-rich with Cu</b>	<b>20</b>	<b>88%</b>		
<b>Pb-rich with P Cu</b>	<b>21</b>	<b>74%</b>	<b>75%</b>	
Pb-rich with P Cu Zn	22	58%		
Pb-rich with Cu Zn	23	81%		
Pb-rich with P Zn	24	50%		
Pb-rich	30			93%
Pb-rich with P	31	79%		80%
Pb-rich with Ba Cu	40			
Pb-rich with Ba P Cu	41			
Pb-rich with Ba	42		69%	
Pb-rich with Ba Cl	43			
Pb-rich with Sn Ba Cu	44			
Pb-rich with Sb Sn P Cu Ba	45	49%		
Pb-rich with Mn	50			32%
Mn-rich with Pb	51		21%	26%
Mn-rich with Pb Cl	52			26%
Pb-rich with Cu Mn P Zn	53	55%		65%
Pb-rich with Mn P Cu	54	31%		
Pb-rich with Mn P	55	39%		
Pb-rich with Cl Cu	60			72%
Pb-rich with Cr	70			85%
<b>Cu-rich with Zn Pb</b>	<b>80</b>	<b>3%</b>		<b>5%</b>
<b>Cu-rich with Zn Pb Cl</b>	<b>81</b>			<b>3%</b>
Cu-rich with Zn Pb Cl Cr Ni P S	82			7%
Pb-rich with S	90			78%
Fe-rich with Pb	100			4%

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Table 3-10. Summary of particle size data. The minimum, maximum, average, and median of the longest diameter of all the lead bearing particles in each sample set is given in micrometers ( $\mu\text{m}$ ). Total number of particles in each set given in Table 3-8. \*Selection for analysis of lead bearing particles from Exide process material and dust samples was generally limited to particles less than 10 to 20 micrometers in size. \*\*The on-site collection of particles on air filters at the Exide facility was limited to particles less than 10 micrometers in size.

Particle Size ( $\mu\text{m}$ )	Exide Battery Facility			Trailer Park		Wooded Areas	Roadside
	Process Material and Dust*	Soil Litter	Air Filters**	Soil Litter	Attic Dust	Soil Litter	Soil Litter
<b>minimum</b>	1.0	0.7	1.5	0.7	1.6	0.5	1.4
<b>maximum</b>	63	45	8.0	220	41	45	12
<b>average</b>	4.3	5.3	3.1	4.4	6.2	4.4	4.4
<b>median</b>	3.2	3.2	3.0	2.1	3.9	2.5	4.2

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Table 4-1. Results of regression calculations, given as  $r^2$ , of **lead** with given element in soil litter from the Exide facility, trailer park, wooded areas, and roadside. Results in **bold** type indicate a statistically significant relationship between lead and the given element at the 99.9% confidence level. n = number of data used in correlation calculation for each data set, except as subscripted in parenthesis. \*negative correlation coefficient, r. NC = not calculated due to abundant data near or below detection limit

Element Regressed with Lead	Exide Facility  Soil Litter  (n = 12)	Westgate Trailer Park  Soil Litter  (n = 80)	Wooded Areas  Soil Litter  (n = 80)	Roadside  Soil Litter  (n = 63)
Aluminum	0.166 *	0.015 *	0.001	<b>0.319 *</b>
Antimony	<b>0.982</b>	<b>0.878</b>	<b>0.941</b> (n = 79)	0.029
Arsenic	NC	0.000 *	NC	NC
Barium	0.043	0.009 *	0.002	0.072
Beryllium	0.025 *	0.025 *	0.025 *	NC
Boron	0.013 *	0.008	0.073 *	0.000 * (n = 62)
Bromine	0.461 (n = 40)	<b>0.508</b> (n = 40)	0.085 (n = 40)	<b>0.406</b> (n = 34)
Calcium	0.012 *	0.009	<b>0.151</b> (n = 78)	0.008
Cobalt	0.076 *	NC	0.015 *	NC
Copper	<b>0.922</b>	0.002	0.055	0.032 * (n = 27)
Iron	0.010 *	0.005 *	0.053	0.096 *
Lanthanum	0.055	0.026 *	0.023	0.011 *
Lithium	0.262 *	0.021 *	0.000 *	0.016 *
Magnesium	0.018 *	0.003	0.088	0.014
Manganese	0.000	0.004	0.021 *	0.038
Phosphorus	0.126	0.005	<b>0.214</b>	<b>0.176</b>
Scandium	0.086 *	0.005 *	0.048	<b>0.240 *</b>
Silicon	0.109 *	0.069 *	<b>0.164 *</b>	0.020
Sodium	0.027 *	0.054 (n = 57)	0.036 (n = 75)	0.003
Strontium	0.019	0.006 *	0.000 *	0.018
Sulfur	<b>0.691</b>	0.029	<b>0.606</b> (n = 78)	<b>0.277</b>
Tin	<b>0.943</b>	0.046	<b>0.516</b>	0.002 (n = 62)
Titanium	0.119 *	0.000 *	0.000	0.004 *
Vanadium	0.080 *	0.010 *	0.018	0.083 *
Yttrium	0.024	0.004	0.006 *	0.007
Zinc	0.135	0.025	0.000 *	<b>0.658</b> (n = 17)

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Table 4-2a. Results of regression calculations, given as  $r^2$ , of iron, scandium, and titanium with each other in soil litter from the Exide facility, trailer park, wooded areas, roadside, and all of these areas combined. Results in **bold** type indicate a statistically significant relationship between the two given elements at the 99.9% confidence level. n = number of data used in correlation calculation for each data set.

Elements Regressed	Exide Facility Soil Litter (n = 12)	Westgate Trailer Park Soil Litter (n = 80)	Wooded Areas Soil Litter (n = 80)	Roadside Soil Litter (n = 63)	All Areas Soil Litter (n = 235)
Iron & Scandium	<b>0.832</b>	<b>0.853</b>	<b>0.858</b>	<b>0.378</b>	<b>0.731</b>
Iron & Titanium	<b>0.787</b>	<b>0.687</b>	<b>0.525</b>	<b>0.322</b>	<b>0.432</b>
Scandium & Titanium	<b>0.862</b>	<b>0.820</b>	<b>0.647</b>	<b>0.220</b>	<b>0.493</b>

Table 4-2b. Average (Avg) soil concentrations plus or minus ( $\pm$ ) one standard deviation (Std Dev) are given in mg/kg dry weight for iron, scandium, and titanium in soil litter from the Exide facility, trailer park, wooded areas, roadside, and all of these areas combined. Relative standard deviations (RSD) are given in percent in parenthesis. Geometric mean concentrations are also given in mg/kg. n = number of data used in calculation of summary statistics for each data set.

Element	Parameter	Exide Facility Soil Litter (n = 12)	Westgate Trailer Park Soil Litter (n = 80)	Wooded Areas Soil Litter (n = 80)	Roadside Soil Litter (n = 63)	All Areas Soil Litter (n = 235)
Iron (mg/kg)	Avg $\pm$ Std Dev	31,200 $\pm$ 7100	22,100 $\pm$ 7200	26,900 $\pm$ 10,800	26,700 $\pm$ 7700	25,400 $\pm$ 9030
	RSD (%)	(23%)	(33%)	(40%)	(29%)	(36%)
	Geometric Mean	30,400	21,100	24,100	25,900	23,800
Scandium (mg/kg)	Avg $\pm$ Std Dev	11.9 $\pm$ 2.7	6.57 $\pm$ 2.63	9.18 $\pm$ 3.27	7.84 $\pm$ 1.55	8.07 $\pm$ 2.98
	RSD (%)	(23%)	(40%)	(36%)	(20%)	(37%)
	Geometric Mean	11.6	6.20	8.40	7.69	7.52
Titanium (mg/kg)	Avg $\pm$ Std Dev	3870 $\pm$ 870	3690 $\pm$ 1070	3530 $\pm$ 1240	3170 $\pm$ 660	3510 $\pm$ 1050
	RSD (%)	(22%)	(29%)	(35%)	(21%)	(30%)
	Geometric Mean	3770	3560	3290	3100	3350

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Table 4-2c. Concentrations in mg/kg of iron, **lead**, scandium, and titanium representing the geometric mean and range in uncultivated soil in northern Georgia (USGS, 1975). Soil litter is part of the "A" soil horizon. The number of data, n, used in the geometric mean calculation was 30, except as subscripted in parenthesis.

Element	Northern Georgia "A" Soil Horizon		Northern Georgia "B" Soil Horizon		Northern Georgia "C" Soil Horizon	
Iron (mg/kg)	21,000	5000-50,000	26,000	7000-70,000	30,000	10,000-50,000
<b>Lead</b> (mg/kg)	21 (n = 27)	<10-70	17 (n = 25)	<10-50	17 (n = 26)	<10-30
Scandium (mg/kg)	86 (n = 29)	<5-15	Not Given		11	5-20
Titanium (mg/kg)	2900	700-5000	3600	1000-7000	3600	1500-7000

Table 4-2d. Results of regression calculations, given as  $r^2$ , of **lead** with lead/antimony, lead/iron, lead/scandium, and lead/titanium in soil litter from the Exide facility, trailer park, wooded areas, roadside, and all of these areas combined. Results in **bold** type indicate a statistically significant relationship between lead and the given lead/element ratio at the 99.9% confidence level. n = number of data used in correlation calculation for each data set, except as subscripted in parenthesis. NC = not calculated due to large differences in regression results for lead and lead/antimony between the roadside and the other areas indicating correlation result for all areas would not be meaningful.

Ratio Regressed with Lead	Exide Facility  Soil Litter  (n = 12)	Westgate Trailer Park  Soil Litter  (n = 80)	Wooded Areas  Soil Litter  (n = 80)	Roadside  Soil Litter  (n = 63)	All Areas  Soil Litter  (n = 235)
Lead/Antimony	0.085	0.097	0.035 (n = 79)	<b>0.684</b>	NC
Lead/Iron	<b>0.995</b>	<b>0.805</b>	<b>0.411</b>	<b>0.965</b>	<b>0.986</b>
Lead/Scandium	<b>0.997</b>	<b>0.781</b>	<b>0.486</b>	<b>0.969</b>	<b>0.985</b>
Lead/Titanium	<b>0.992</b>	<b>0.800</b>	<b>0.599</b>	<b>0.953</b>	<b>0.988</b>

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Table 4-2e. Results of regression calculations, given as  $r^2$ , of **lead** and lead/iron, lead/scandium, and lead/titanium in the “upper” and “lower” mineral soil in the trailer park. Results in **bold** type indicate a statistically significant relationship between lead and the given lead/element ratio at the 99.9% confidence level. All other results indicate a statistically significant relationship between lead and the given lead/element ratio at the 99% confidence level. n = number of data used in correlation calculation for each data set.

Ratio Regressed with Lead	Westgate Trailer Park  Soil Litter  (n = 7)	Westgate Trailer Park  “Upper” Mineral Soil  (n = 7)	Westgate Trailer Park  “Lower” Mineral Soil  (n = 7)
Lead/Iron	0.857	0.843	<b>0.965</b>
Lead/Scandium	0.857	0.849	<b>0.949</b>
Lead/Titanium	0.848	0.874	<b>0.912</b>

Table 4-3. Results of statistical tests for the comparison of concentration medians of antimony, **lead**, and tin in soil litter from the trailer park, Exide facility, wooded areas, and roadside. Results of the Mann-Whitney statistical test comparing concentration medians between two areas are given as P-values, where P-values below 0.05 indicate a statistically significant difference between the two medians at the 95% confidence level. n = number of data used in calculation for each data set (except 79 for antimony in the wooded areas and 62 for tin along the roadside).

**Comparison of Elemental Concentrations in Soil Litter**

Soil Areas Compared	P-values		
	Antimony	<b>Lead</b>	Tin
Westgate Trailer Park (n = 80) and Exide Facility (n = 12)	0.000	0.000	0.000
<b>Westgate Trailer Park (n = 80)</b> <b>and Wooded Areas (n = 80)</b>	<b>0.054</b>	<b>0.532</b>	<b>0.367</b>
Westgate Trailer Park (n = 80) and Roadside (n = 63)	0.000	0.000	0.000
Exide Facility (n = 12) and Wooded Areas (n = 80)	0.000	0.000	0.000
Exide Facility (n = 12) and Roadside (n = 63)	0.000	0.000	0.000
Wooded Areas (n = 80) and Roadside (n = 63)	0.000	0.000	0.000



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Table 4-4. Source apportionment of bulk soil lead. a) Estimated proportion of lead in the soil litter of the given area attributable to natural background based on USGS (1975) regional geometric mean for lead of 21 mg/kg (Table 4-2c) b) Maximum proportion of lead in the soil litter of the given area attributable to automobiles based on the proportion of average lead concentration attributable to anthropogenic contamination in the roadside soil litter. c) Estimated proportion of lead in the soil litter of the given area attributable to automobiles based on the ratio of average lead concentration to average bromine concentration in the roadside soil litter. Lower results based on a bromine background concentration of 5.5 mg/kg. Higher results based on a bromine background concentration of 0.0 mg/kg. Negative results were rounded to 0%. d) Estimated proportion of lead in the soil litter of the given area attributable to the Exide facility based on the ratio of average lead concentration to average antimony concentration in the Exide soil litter. Lower results based on an antimony background concentration of 0.53 mg/kg. Higher results based on an antimony background concentration of zero mg/kg. Data summary in Table 3-2. NC = not calculated due to the lack of correlation between lead and antimony in bulk soil analyses and the lack of lead-antimony-tin particles in individual particle analysis.

<b>Lead Source</b>	<b>Exide Soil Litter</b>	<b>Trailer Park Soil Litter</b>	<b>Wooded Areas Soil Litter</b>	<b>Roadside Soil Litter</b>
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a) Estimated proportion of lead in soil litter attributable to natural background

<b>Natural Background</b>	<b>0.1%</b>	<b>2.6%</b>	<b>2.2%</b>	<b>13%</b>
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b) Maximum proportion of lead in soil litter attributable to automobiles based on relative lead concentrations:

<b>Automobiles</b>	<b>0.9%</b>	<b>18%</b>	<b>15%</b>	<b>87%</b>
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c) Calculation results of the estimated proportion of lead in soil litter attributable to automobiles:

<b>Automobiles</b>	<b>0.0 to 0.4%</b>	<b>8.3 to 13%</b>	<b>2.8 to 8.6%</b>	<b>87%</b>
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d) Calculation results of the estimated proportion of lead in soil litter attributable to the Exide facility based on relative lead to antimony concentration ratios:

<b>Exide Battery Facility</b>	<b>99.9%</b>	<b>80 to 89%</b>	<b>114 to 122%</b>	<b>NC</b>
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Table 4-5. Source apportionment of **lead** bearing particles. a) Lead source apportionment based on particle count given as a percent of total lead bearing particles. The number of lead bearing particles from each source for each sample set is given in parenthesis. Data summary found in Table 3-8. b) Lead source apportionment based on particle size given as a percent of the sum of the longest diameter of particles in micrometers ( $\mu\text{m}$ ). The sum of the longest diameter of particles from each source for each sample set is given in parenthesis. c) Lead source apportionment based on estimated weight percent of lead in particles from identified sources given as a percent of lead by weight. \*apportionment of these lead particle classes in the trailer park and wooded area soil was based on the proportion of lead "oxide" particles attributable to automobile exhaust from roadside lead particle data. Thus, 6.3% of total lead bearing particles in a receptor soil not including lead-antimony-tin particles were included as lead "oxide" particles from the automobile exhaust source, the remaining portion was included in the Exide battery facility source. Fractional particles were rounded to nearest whole particle.

<b>Lead Particle Source</b>	<b>Particle Class Identifiers</b>	<b>Exide Soil Litter</b>	<b>Trailer Park Soil Litter</b>	<b>Wooded Areas Soil Litter</b>	<b>Roadside Soil Litter</b>
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a) Lead source apportionment based on particle count:

<b>Exide Battery Facility</b>	1-4, 10-19, 20-24* 30-31*, 40-45	<b>100%</b> (60)	<b>91%</b> (111)	<b>89%</b> (33)	
<b>Vehicle Brake Dust</b>	80-82		<b>1%</b> (1)		<b>41%</b> (13)
<b>Automobile Exhaust</b>	20-24*, 30-31* 52, 60, 90		<b>4%</b> (5)		<b>13%</b> (4)
<b>Road Paint</b>	70				<b>6%</b> (2)
<b>Undetermined</b>	50-51, 53-55, 100		<b>4%</b> (5)	<b>11%</b> (4)	<b>41%</b> (13)
Total Particles Analyzed		60	122	37	32

b) Lead source apportionment based on the long diameter of lead bearing particles:

<b>Exide Battery Facility</b>	1-4, 10-19, 20-24* 30-31*, 40-45	<b>100%</b> (319 8)	<b>91%</b> (490 1)	<b>60%</b> (98 7)	
<b>Vehicle Brake Dust</b>	80-82		<b>1%</b> (3 6)		<b>35%</b> (49 3)
<b>Automobile Exhaust</b>	20-24*, 30-31* 52, 60, 90		<b>4%</b> (24.1)		<b>19%</b> (26.7)
<b>Road Paint</b>	70				<b>3%</b> (4 6)
<b>Undetermined</b>	50-51, 53-55, 100		<b>4%</b> (20 8)	<b>40%</b> (64 6)	<b>42%</b> (59 3)

c) Estimated weight percent of lead bearing particles:

<b>Exide Battery Facility</b>	1-4, 10-19, 20-24* 30-31*, 40-45	<b>100%</b>	<b>93%</b>	<b>79%</b>	
<b>Vehicle Brake Dust</b>	80-82		<b>0.03%</b>		<b>6%</b>
<b>Automobile Exhaust</b>	20-24*, 30-31* 52, 60, 90		<b>5%</b>		<b>52%</b>
<b>Road Paint</b>	70				<b>10%</b>
<b>Undetermined</b>	50-51, 53-55, 100		<b>2%</b>	<b>21%</b>	<b>33%</b>

**APPENDIX A**

**Results of Bulk Elemental Analysis**

APPENDIX A

Results of Bulk Elemental Analysis

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# 1 INTRODUCTION

Data results for bulk elemental analysis of the following are presented in this appendix: soil litter in the Westgate Trailer Park, "upper" mineral soil in the Westgate Trailer Park, "lower" mineral soil in the Westgate Trailer Park, attic dust in the Westgate Trailer Park, soil litter at the Exide facility, process material and dust at the Exide facility, soil litter in the wooded areas, and soil litter along the roadside. Results are reported in all sample sets for: aluminum, antimony, arsenic, barium, beryllium, boron, cadmium, calcium, cobalt, copper, iron, lanthanum, lead, lithium, magnesium, manganese, phosphorus, scandium, selenium, silicon, sodium, strontium, sulfur, tin, titanium, vanadium, yttrium, and zinc. Bromine was reported for all sample sets except for the "upper" and "lower" mineral soil in the Westgate Trailer Park. In addition, silver was reported for the trailer park attic dust and wooded area soil litter.

Soil subsamples were dried before being entirely ground prior to dissolution and analysis. The following table gives the average dry weight of soil litter in soil cores from each area and the average percentage of water by weight present in the soil litter in each area.

	Exide Facility	Westgate Trailer Park	Wooded Areas	Roadside
Average Dry Soil Litter (grams)	60.6	52.5	38.7	39.1
Average Percent Water (%)	12.8	14.3	28.2	14.3

Dissolution and analytical techniques used for determining bulk chemical composition are summarized in Table 2-3. All soil litter subsamples collected were analyzed. Only seven "upper" mineral soil subsamples and the corresponding "lower" mineral soil subsamples from the trailer park were analyzed. The following abbreviations and chemical formulas are used in this appendix for describing the dissolution and analytical techniques employed in determining the various analytes: ICP = inductively coupled plasma, OES = optical emission spectroscopy, Hyd Gen = hydride generation, MS = mass spectrometry, KOH = potassium hydroxide, HNO<sub>3</sub> = nitric acid, HCl = hydrochloric acid, INAA = instrumental neutron activation analysis.

The following abbreviations were also used in these data tables: MDL = method detection limit, ND = not detected, NA = not analyzed due to insufficient sample, NR = not reported due to gross error encountered during analysis, NS = not submitted to the USGS for analysis due to resource constraints.

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2. WESTGATE TRAILER PARK

2.1. Results of Bulk Elemental Analysis of Soil Litter in the Westgate Trailer Park

Element	Analyses by ICP-OES on KOH fusions except as noted				
	01A	01B	01C	01D	02A
	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)
Aluminum	49600	59800	50800	40100	47500
Antimony (a)	6 76	5 96	7.18	5.62	3 49
Arsenic (d)	12	13	12	10	4
Barium	100	79	114	97	499
Beryllium	6 5	3 7	3 8	3 0	2 1
Boron	259	246	278	200	57
Bromine (c)	NS	7 8	NS	8.59	NS
Cadmium (e)	ND	ND	0.4	0 6	0 6
Calcium	1800	1700	3300	18900	3500
Cobalt	ND	ND	ND	ND	ND
Copper	13	17	17	21	ND
Iron	19000	23300	18700	16100	15700
Lanthanum	41	36	42	32	18
Lead	983	1240	1210	973	801
Lithium	19	21	20	21	11
Magnesium	900	810	1100	1010	1010
Manganese	127	130	189	161	226
Phosphorus	790	820	900	850	500
Scandium	4 6	6 1	5 3	4 5	4.4
Selenium	ND	ND	ND	ND	ND
Silicon	359000	315000	328000	293000	341000
Sodium	800	ND	ND	800	2500
Strontium	26 8	20 8	30 8	87.8	76 7
Sulfur	560	560	590	8610	490
Tin	8	9	8	7	7
Titanium	3180	3200	3680	2550	2300
Vanadium	49	60	51	43	35
Yttrium	30	35	34	29	11
Zinc	160	210	250	510	90
					MDL
					(mg/kg)
					200
					0.04
					2
					1
					0 2
					8
					0 5
					0 4
					400
					4
					8
					30
					6
					2
					4
					70
					3
					20
					0 4
					50
					100
					800
					0 8
					70
					2
					20
					4
					2
					20

(a) Analyses by ICP-MS on HCl digestions  
 (b) Analyses by Hyd Gen / ICP-MS on KOH fusions  
 (c) Analyses by INAA  
 (d) Analyses by Hyd Gen / ICP-OES on KOH fusions  
 (e) Analyses by ICP-MS on HNO<sub>3</sub> digestions

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2.1. Results of Bulk Elemental Analysis of Soil Litter in the Westgate Trailer Park (continued)

Analyses by ICP-OES on KOH fusions except as noted  
 (a) Analyses by ICP-MS on HCl digestions (d) Analyses by Hyd Gen / ICP-OES on KOH fusions  
 (b) Analyses by Hyd Gen / ICP-MS on KOH fusions (e) Analyses by ICP-MS on HNO<sub>3</sub> digestions  
 (c) Analyses by INAA

Element	02B (mg/kg)	02C (mg/kg)	02D (mg/kg)	03A (mg/kg)	03B (mg/kg)	MDL (mg/kg)
Aluminum	60800	55000	59500	54100	54300	200
Antimony (a)	3 34	3 71	3 90	3 36	7 37	0.04
Arsenic (d)	6	8	9	11	8	2
Barium	509	429	286	88	101	1
Beryllium	1 9	2 4	5 3	4 4	3 3	0 2
Boron	56	110	185	401	316	8
Bromine (c)	5 74	6 47	NS	NS	NS	0 5
Cadmium (e)	ND	0 4	0.6	ND	0 8	0.4
Calcium	2900	3300	3500	800	2100	400
Cobalt	ND	ND	ND	ND	ND	4
Copper	13	12	20	15	15	8
Iron	20900	19300	22900	23100	21900	30
Lanthanum	33	32	32	44	40	6
Lead (e)	561	869	836	559	1100	2
Lithium	21	20	22	23	22	4
Magnesium	1110	1130	1230	920	980	70
Manganese	221	231	208	91	124	3
Phosphorus	660	530	690	740	950	20
Scandium	6.5	5.6	6.7	5 5	5 4	0 4
Selenium	ND	ND	ND	ND	ND	50
Silicon	357000	343000	322000	352000	272000	100
Sodium	2200	2100	1600	ND	ND	800
Strontium	76.2	69 0	54.7	20 0	24 3	0 8
Sulfur	290	440	510	320	780	70
Tin (b)	8	6	15	7	9	2
Titanium	3190	2910	3230	3270	2730	20
Vanadium	57	52	53	60	49	4
Yttrium	17	15	21	45	30	2
Zinc	100	100	130	110	280	20

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2.1. Results of Bulk Elemental Analysis of Soil Litter in the Westgate Trailer Park (continued)

Analyses by ICP-OES on KOH fusions except as noted  
 (a) Analyses by ICP-MS on HCl digestions (d) Analyses by Hyd Gen / ICP-OES on KOH fusions  
 (b) Analyses by Hyd Gen / ICP-MS on KOH fusions (e) Analyses by ICP-MS on HNO<sub>3</sub> digestions  
 (c) Analyses by INAA

Element	03C (mg/kg)	03D (mg/kg)	04A (mg/kg)	04B (mg/kg)	04C (mg/kg)	MDL (mg/kg)
Aluminum (a)	42600	38500	56600	36200	54900	200
Antimony (d)	7 61	5 57	6.18	5 07	6 87	0 04
Arsenic	8	9	8	3	8	2
Barium	106	91	246	187	236	1
Beryllium	2.9	3 7	4 2	2 1	4.1	0 2
Boron	283	281	179	160	219	8
Bromine (c)	9 50	7 28	NS	9.71	NS	0 5
Cadmium (e)	0 8	0 9	1 1	0 7	0 8	0 4
Calcium	3700	2500	4100	4000	4600	400
Cobalt	ND	ND	ND	ND	ND	4
Copper	12	15	31	13	31	8
Iron	15400	16000	33700	12400	22900	30
Lanthanum	33	33	38	33	41	6
Lead (e)	976	834	1430	642	1170	2
Lithium	21	21	30	21	29	4
Magnesium	1020	900	1510	1140	1530	70
Manganese	143	157	354	179	333	3
Phosphorus	780	960	1190	700	1250	20
Scandium	4.0	3 5	6.4	3 6	5 9	0 4
Selenium	ND	ND	ND	ND	ND	50
Silicon	311000	320000	288000	342000	278000	100
Sodium	ND	ND	3600	4000	2400	800
Strontium	28 3	24 1	62 3	53 1	59 7	0 8
Sulfur	760	550	910	660	820	70
Tin (b)	9	9	14	8	14	2
Titanium	2480	2490	3360	2010	3160	20
Vanadium	39	42	54	28	50	4
Yttrium	28	40	21	20	22	2
Zinc	310	390	250	130	200	20



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2.1. Results of Bulk Elemental Analysis of Soil Litter in the Westgate Trailer Park (continued)

Analyses by ICP-OES on KOH fusions except as noted  
 (a) Analyses by ICP-MS on HCl digestions (d) Analyses by Hyd Gen / ICP-OES on KOH fusions  
 (b) Analyses by Hyd Gen / ICP-MS on KOH fusions (e) Analyses by ICP-MS on HNO<sub>3</sub> digestions  
 (c) Analyses by INAA

Element	04D (mg/kg)	05A (mg/kg)	05B (mg/kg)	05C (mg/kg)	05D (mg/kg)	MDL (mg/kg)
Aluminum	43200	37400	41700	36300	42900	200
Antimony (a)	3 99	7.76	10 7	7 17	12 8	0 04
Arsenic (d)	9	8	10	9	8	2
Barium	160	93	115	96	156	1
Beryllium	4 0	5 0	3 4	5 5	5 4	0 2
Boron	261	415	278	386	368	8
Bromine (c)	9 40	NS	9 09	NS	12.9	0 5
Cadmium (e)	0 7	ND	0 6	ND	0.7	0 4
Calcium	2700	1000	3900	1600	4400	400
Cobalt	ND	ND	ND	ND	ND	4
Copper	14	13	12	13	16	8
Iron	16000	12800	19800	15000	14800	30
Lanthanum	36	49	41	44	45	6
Lead (e)	836	1470	1610	1340	2550	2
Lithium	22	20	20	21	23	4
Magnesium	1200	920	1140	970	1480	70
Manganese	210	92	177	133	192	3
Phosphorus	970	760	890	720	860	20
Scandium	5 0	3 8	4 3	3 9	5 0	0 4
Selenium	ND	ND	ND	ND	ND	50
Silicon	325000	365000	291000	360000	296000	100
Sodium	1800	ND	ND	ND	ND	800
Strontium	42 7	24.0	36 6	24 7	42 2	0 8
Sulfur	760	420	900	420	780	70
Tin (b)	8	10	12	9	16	2
Titanium	2680	2670	2630	2600	2940	20
Vanadium	41	38	47	41	47	4
Yttrium	26	35	21	33	30	2
Zinc	140	80	160	100	260	20

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**2.1. Results of Bulk Elemental Analysis of Soil Litter in the Westgate Trailer Park (continued)**

Analyses by ICP-OES on KOH fusions except as noted  
 (a) Analyses by ICP-MS on HCl digestions (d) Analyses by Hyd Gen / ICP-OES on KOH fusions  
 (b) Analyses by Hyd Gen / ICP-MS on KOH fusions (e) Analyses by ICP-MS on HNO<sub>3</sub> digestions  
 (c) Analyses by INAA

Element	06A	06B	06C	06D	07A	MDL
	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)
Aluminum	44500	46300	45700	54500	97800	200
Antimony (a)	5 29	4 61	5.14	5 94	5 57	0 04
Arsenic (d)	7	9	7	6	22	2
Barium	157	136	131	398	722	1
Beryllium	4 5	4 6	4 0	2 9	8 7	0 2
Boron	237	276	250	120	184	8
Bromine (c)	NS	5 51	NS	NS	5 16	0 5
Cadmium (e)	1 8	0 7	0.8	0.4	0 8	0 4
Calcium	2500	1900	2400	6700	1600	400
Cobalt	ND	ND	NR	5	10	4
Copper	20	14	8	23	36	8
Iron	15500	16200	13300	18200	48700	30
Lanthanum	42	49	46	41	147	6
Lead	887	1050	645	819	620	2
Lithium	24	26	21	24	71	4
Magnesium	970	1010	980	1960	4810	70
Manganese	145	104	103	228	321	3
Phosphorus	940	730	870	840	1700	20
Scandium	4 4	4 6	4 5	5 2	18 9	0 4
Selenium	ND	ND	ND	ND	ND	50
Silicon	333000	353000	344000	274000	233000	100
Sodium	ND	ND	800	9700	900	800
Strontium	48.1	39 1	42 4	108	245	0 8
Sulfur	620	420	630	1350	390	70
Tin	10	9	8	9	14	2
Titanium	2910	3070	2990	2380	7660	20
Vanadium	41	46	41	41	130	4
Yttrium	24	29	19	39	39	2
Zinc	130	80	110	230	120	20

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2.1. Results of Bulk Elemental Analysis of Soil Litter in the Westgate Trailer Park (continued)

Analyses by ICP-OES on KOH fusions except as noted  
 (a) Analyses by ICP-MS on HCl digestions (d) Analyses by Hyd Gen / ICP-OES on KOH fusions  
 (b) Analyses by Hyd Gen / ICP-MS on KOH fusions (e) Analyses by ICP-MS on HNO<sub>3</sub> digestions  
 (c) Analyses by INAA

Element	07B (mg/kg)	07C (mg/kg)	07D (mg/kg)	08A (mg/kg)	08B (mg/kg)	MDL (mg/kg)
Aluminum	81300	88300	61300	69000	84000	200
Antimony (a)	4 81	5 22	5 85	7 05	10 8	0 04
Arsenic (d)	13	14	13	10	11	2
Barium	476	640	396	268	283	1
Beryllium	7 3	5 0	5 1	4 3	3 4	0 2
Boron	230	186	262	227	144	8
Bromine (c)	NS	5 37	NS	NS	NS	0 5
Cadmium (e)	0 5	0 7	0 6	1 3	1 5	0 4
Calcium	3700	1500	2100	3700	4200	400
Cobalt	ND	10	ND	8	5	4
Copper	25	30	19	23	28	8
Iron	34500	44000	27700	25800	30600	30
Lanthanum	106	148	86	49	44	6
Lead (e)	625	686	718	1210	2050	2
Lithium	51	62	38	31	42	4
Magnesium	2900	3990	2150	1550	1900	70
Manganese	250	315	228	322	366	3
Phosphorus	2300	1650	1240	1300	1500	20
Scandium	12 9	17 0	9 4	8 2	9 6	0 4
Selenium	ND	ND	ND	ND	ND	50
Silicon	275000	253000	322000	296000	240000	100
Sodium	1100	ND	900	2100	2400	800
Strontium	166	214	132	66 8	67 5	0 8
Sulfur	490	520	530	940	1150	70
Tin (b)	12	12	11	14	22	2
Titanium	6480	7230	5920	5170	5560	20
Vanadium	92	115	75	79	82	4
Yttrium	32	34	32	29	25	2
Zinc	120	130	160	230	260	20

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2.1. Results of Bulk Elemental Analysis of Soil Litter in the Westgate Trailer Park (continued)

Analyses by ICP-OES on KOH fusions except as noted  
 (a) Analyses by ICP-MS on HCl digestions (d) Analyses by Hyd Gen / ICP-OES on KOH fusions  
 (b) Analyses by Hyd Gen / ICP-MS on KOH fusions (e) Analyses by ICP-MS on HNO<sub>3</sub> digestions  
 (c) Analyses by INAA

Element	08C (mg/kg)	08D (mg/kg)	09A (mg/kg)	09B (mg/kg)	09C (mg/kg)	MDL (mg/kg)
Aluminum	78600	67900	65700	53900	63700	200
Antimony (a)	10 7	8 59	14 1	9 68	8 78	0 04
Arsenic (d)	10	9	10	9	11	2
Barium	278	263	231	209	197	1
Beryllium	3.9	3 9	3 7	4 2	4 9	0 2
Boron	239	194	235	332	318	8
Bromine (c)	18 2	13 9	NS	14 8	15 0	0 5
Cadmium (e)	1 2	0.9	1 5	1 2	1 1	0 4
Calcium	3300	3000	2500	2700	2600	400
Cobalt	5	ND	ND	ND	ND	4
Copper	33	24	35	28	23	8
Iron	27300	23300	22800	19200	21500	30
Lanthanum	54	44	48	47	49	6
Lead (e)	2050	1390	2760	1610	1670	2
Lithium	40	35	34	27	28	4
Magnesium	1770	1500	1620	1420	1450	70
Manganese	356	253	229	226	225	3
Phosphorus	1320	1020	1250	1080	1000	20
Scandium	8.9	7 1	7 0	5 8	6 3	0 4
Selenium	ND	ND	ND	ND	ND	50
Silicon	270000	304000	276000	310000	308000	100
Sodium	2400	3300	2300	2400	1600	800
Strontium	70 2	67.8	54.5	51 3	47 7	0.8
Sulfur	980	760	1020	920	830	70
Tin (b)	18	15	20	15	15	2
Titanium	5310	4630	4290	3550	4260	20
Vanadium	77	62	60	51	58	4
Yttrium	28	23	35	28	30	2
Zinc	230	160	220	200	190	20

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**2.1. Results of Bulk Elemental Analysis of Soil Litter in the Westgate Trailer Park (continued)**

Analyses by ICP-OES on KOH fusions except as noted  
 (a) Analyses by ICP-MS on HCl digestions (d) Analyses by Hyd Gen / ICP-OES on KOH fusions  
 (b) Analyses by Hyd Gen / ICP-MS on KOH fusions (e) Analyses by ICP-MS on HNO<sub>3</sub> digestions  
 (c) Analyses by INAA

Element	09D	10A	10B	10C	10D	MDL
	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)
Aluminum	62400	55100	69700	52600	64600	200
Antimony (a)	9 60	2 38	3 80	3 35	2 45	0 04
Arsenic (d)	9	6	57	7	9	2
Barium	185	198	243	181	200	1
Beryllium	4 6	7 3	4 0	3 9	7 2	0 2
Boron	289	280	260	264	323	8
Bromine (c)	NS	NS	8 21	10 2	NS	0 5
Cadmium (e)	1 1	0 5	1 2	0 5	0 4	0 4
Calcium	2400	7700	5100	13800	3100	400
Cobalt	ND	ND	ND	4	ND	4
Copper	36	21	101	17	16	8
Iron	20900	20200	27700	19000	22200	30
Lanthanum	49	61	57	56	62	6
Lead	1660	572	602	1310	549	2
Lithium	28	31	39	28	34	4
Magnesium	1370	1490	1540	1940	1270	70
Manganese	225	190	351	181	198	3
Phosphorus	980	770	850	810	760	20
Scandium	6.6	6 6	8 3	6 6	7 5	0 4
Selenium	ND	ND	ND	ND	ND	50
Silicon	298000	329000	292000	302000	274000	100
Sodium	1600	1300	2100	1400	1200	800
Strontium	48.5	56 6	65 3	62 6	53 0	0 8
Sulfur	680	570	580	700	560	70
Tin	14	8	9	8	8	2
Titanium	3900	3530	4390	3310	3690	20
Vanadium	53	58	75	59	64	4
Yttrium	30	31	31	27	30	2
Zinc	220	170	340	360	130	20

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2.1. Results of Bulk Elemental Analysis of Soil Litter in the Westgate Trailer Park (continued)

Element	Analyses by ICP-OES on KOH fusions except as noted				MDL	
	11A	11B	11C	11D	12A	(mg/kg)
Aluminum	44600	39700	39200	47800	54000	200
Antimony (a)	2 51	4 48	3 49	3 07	2 70	0.04
Arsenic (d)	8	6	7	6	9	2
Barium	205	203	187	187	171	1
Beryllium	4 5	4 9	4.3	4 5	5 8	0.2
Boron	313	265	251	315	283	8
Bromine (c)	NS	13 5	7 64	NS	NS	0 5
Cadmium (e)	ND	0 4	0 4	0 4	0 4	0 4
Calcium	1900	3000	2600	1700	4400	400
Cobalt	NR	ND	ND	ND	ND	4
Copper	33	32	53	24	21	8
Iron	13300	13600	13500	16000	18500	30
Lanthanum	54	56	41	47	48	6
Lead (e)	321	876	613	367	679	2
Lithium	25	19	22	28	26	4
Magnesium	980	960	910	970	1150	70
Manganese	297	277	246	205	163	3
Phosphorus	920	990	890	850	1700	20
Scandium	4 5	4 4	3 6	4 9	6 2	0 4
Selenium	ND	ND	ND	ND	ND	50
Silicon	377000	377000	401000	379000	345000	100
Sodium	ND	900	1400	800	1600	800
Strontium	43 3	50 0	46 1	43 3	45 1	0 8
Sulfur	230	420	280	270	470	70
Tin (b)	15	15	23	16	9	2
Titanium	3330	2900	2690	3430	3180	20
Vanadium	44	44	38	48	55	4
Yttrium	35	34	29	34	27	2
Zinc	130	140	130	170	270	20

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2.1. Results of Bulk Elemental Analysis of Soil Litter in the Westgate Trailer Park (continued)

Analyses by ICP-OES on KOH fusions except as noted  
 (a) Analyses by ICP-MS on HCl digestions (d) Analyses by Hyd Gen / ICP-OES on KOH fusions  
 (b) Analyses by Hyd Gen / ICP-MS on KOH fusions (e) Analyses by ICP-MS on HNO<sub>3</sub> digestions  
 (c) Analyses by INAA

Element	12B (mg/kg)	12C (mg/kg)	12D (mg/kg)	13A (mg/kg)	13B (mg/kg)	MDL (mg/kg)
Aluminum	49500	55600	47800	60700	53900	200
Antimony (a)	4 02	3 31	4 29	3 89	2 45	0 04
Arsenic (d)	6	6	7	7	9	2
Barium	184	170	156	252	199	1
Beryllium	3 6	4 3	4 0	5 9	7 0	0 2
Boron	204	248	242	284	294	8
Bromine (c)	14 1	NS	10 6	NS	5 53	0 5
Cadmium (e)	0.7	0 5	0 6	0 5	0 4	0 4
Calcium	4200	2800	2900	3900	4200	400
Cobalt	ND	ND	5	ND	ND	4
Copper	18	21	20	27	28	8
Iron	18400	17000	17200	23000	19300	30
Lanthanum	40	41	38	49	42	6
Lead (e)	641	526	817	836	474	2
Lithium	25	22	23	26	30	4
Magnesium	1440	1520	1390	1410	1470	70
Manganese	240	197	197	315	259	3
Phosphorus	1050	990	940	1130	1020	20
Scandium	5 3	4 8	4 9	6 6	6 0	0 4
Selenium	ND	ND	ND	ND	ND	50
Silicon	308000	319000	310000	340000	330000	100
Sodium	2700	1700	1500	3300	1200	800
Strontium	51 1	42 3	38 8	63 4	49 2	0 8
Sulfur	900	680	730	510	500	70
Tin (b)	9	8	10	15	15	2
Titanium	2720	2780	2820	3390	3040	20
Vanadium	46	47	51	59	53	4
Yttrium	24	27	45	31	25	2
Zinc	200	210	200	190	150	20

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**2.1. Results of Bulk Elemental Analysis of Soil Litter in the Westgate Trailer Park (continued)**

Analyses by ICP-OES on KOH fusions except as noted  
 (a) Analyses by ICP-MS on HCl digestions (d) Analyses by Hyd Gen / ICP-OES on KOH fusions  
 (b) Analyses by Hyd Gen / ICP-MS on KOH fusions (e) Analyses by ICP-MS on HNO<sub>3</sub> digestions  
 (c) Analyses by INAA

Element	13C	13D	14A	14B	14C	MDL
	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)
Aluminum	47000	61400	87200	66000	84000	200
Antimony (a)	3 86	3.66	3 71	3 77	3 74	0 04
Arsenic (d)	6	7	11	10	10	2
Barium	238	288	161	173	173	1
Beryllium	4 2	7 9	3.5	3.6	3 4	0.2
Boron	296	289	159	232	171	8
Bromine (c)	6 57	NS	NS	5 71	NS	0 5
Cadmium (e)	0.6	0 6	0 4	0 6	0.4	0 4
Calcium	3500	4500	1700	2800	2300	400
Cobalt	ND	ND	ND	ND	ND	4
Copper	39	29	42	25	20	8
Iron	16400	21300	31900	22400	27000	30
Lanthanum	45	49	50	44	43	6
Lead (e)	693	669	418	371	445	2
Lithium	29	26	42	34	40	4
Magnesium	1460	1400	1170	1040	1050	70
Manganese	302	344	145	172	139	3
Phosphorus	1150	1190	880	900	990	20
Scandium	6 2	6 0	8 7	5 9	8 0	0 4
Selenium	ND	ND	ND	ND	ND	50
Silicon	276000	373000	297000	336000	272000	100
Sodium	3700	2800	ND	ND	800	800
Strontium	56 1	65 2	42 0	41 1	40 4	0 8
Sulfur (b)	650	690	440	500	440	70
Tin	19	17	12	10	10	2
Titanium	2660	3630	4370	3580	3950	20
Vanadium	54	56	78	58	72	4
Yttrium	23	27	25	29	23	2
Zinc	210	220	190	150	130	20



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2.1. Results of Bulk Elemental Analysis of Soil Litter in the Westgate Trailer Park (continued)

Analyses by ICP-OES on KOH fusions except as noted  
 (a) Analyses by ICP-MS on HCl digestions (d) Analyses by Hyd Gen / ICP-OES on KOH fusions  
 (b) Analyses by Hyd Gen / ICP-MS on KOH fusions (e) Analyses by ICP-MS on HNO<sub>3</sub> digestions  
 (c) Analyses by INAA

Element	14D (mg/kg)	15A (mg/kg)	15B (mg/kg)	15C (mg/kg)	15D (mg/kg)	MDL (mg/kg)
Aluminum	77800	83000	74600	87900	103000	200
Antimony (a)	3 00	2 72	2 68	3 27	3 94	0.04
Arsenic (d)	12	14	11	15	14	2
Barium	129	236	208	261	285	1
Beryllium	4 8	4 4	4 5	4 5	3.8	0 2
Boron	169	128	188	132	109	8
Bromine (c)	5 47	NS	7 41	9 35	NS	0 5
Cadmium (e)	ND	0 6	0 4	0 7	0 7	0 4
Calcium	1300	4100	2200	4700	2500	400
Cobalt	ND	ND	6	5	ND	4
Copper	19	29	24	23	29	8
Iron	27400	30600	24400	30800	44600	30
Lanthanum	43	54	55	60	77	6
Lead (e)	316	440	400	541	527	2
Lithium	39	42	39	42	43	4
Magnesium	970	1470	1160	1600	1220	70
Manganese	119	233	192	263	170	3
Phosphorus	620	940	940	1070	1160	20
Scandium	7.0	8 5	8 1	9 9	13 1	0 4
Selenium	ND	ND	ND	ND	60	50
Silicon	318000	284000	258000	255000	269000	100
Sodium	ND	ND	1300	900	ND	800
Strontium	33.8	65 4	52 9	74 3	100	0 8
Sulfur	330	530	510	670	480	70
Tin (b)	11	11	7	11	16	2
Titanium	3580	4360	4130	4770	5630	20
Vanadium	72	88	69	80	105	4
Yttrium	24	23	38	27	20	2
Zinc	110	280	190	260	490	20

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2.1. Results of Bulk Elemental Analysis of Soil Litter in the Westgate Trailer Park (continued)

Analyses by ICP-OES on KOH fusions except as noted  
 (a) Analyses by ICP-MS on HCl digestions (d) Analyses by Hyd Gen / ICP-OES on KOH fusions  
 (b) Analyses by Hyd Gen / ICP-MS on KOH fusions (e) Analyses by ICP-MS on HNO<sub>3</sub> digestions  
 (c) Analyses by INAA

Element	16A (mg/kg)	16B (mg/kg)	16C (mg/kg)	16D (mg/kg)	17A (mg/kg)	MDL (mg/kg)
Aluminum	79100	76900	78000	82400	53900	200
Antimony (a)	2 89	3 05	2 15	3 21	2 36	0 04
Arsenic (d)	11	12	12	13	7	2
Barium	167	166	142	163	211	1
Beryllium	3.3	3 5	4 0	3 6	5.1	0 2
Boron	330	450	335	341	258	8
Bromine (c)	NS	10 6	7 81	NS	NS	0 5
Cadmium (e)	0 4	ND	0.6	0 9	ND	0 4
Calcium	2000	1800	4000	2600	2800	400
Cobalt	ND	ND	NR	NR	ND	4
Copper	16	18	16	17	16	8
Iron	26600	27100	28700	32700	19300	30
Lanthanum	44	51	46	38	50	6
Lead (e)	466	512	301	460	336	2
Lithium	36	37	35	42	26	4
Magnesium	1200	1420	1180	1290	1170	70
Manganese	195	196	187	180	238	3
Phosphorus	950	950	1660	1110	1030	20
Scandium	7.6	8 9	9 0	8 1	5 3	0 4
Selenium	ND	ND	ND	ND	ND	50
Silicon	288000	290000	279000	271000	358000	100
Sodium	ND	1100	1200	1000	1000	800
Strontium	42 1	38 8	43 7	37 6	50 4	0 8
Sulfur	560	480	490	630	520	70
Tin (b)	8	8	8	10	10	2
Titanium	4400	4340	4090	4260	4300	20
Vanadium	69	76	79	73	52	4
Yttrium	28	31	23	22	29	2
Zinc	270	360	200	250	250	20

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2.1 Results of Bulk Elemental Analysis of Soil Litter in the Westgate Trailer Park (continued)

Analyses by ICP-OES on KOH fusions except as noted  
 (a) Analyses by ICP-MS on HCl digestions (d) Analyses by Hyd Gen / ICP-OES on KOH fusions  
 (b) Analyses by Hyd Gen / ICP-MS on KOH fusions (e) Analyses by ICP-MS on HNO<sub>3</sub> digestions  
 (c) Analyses by INAA

Element	17B (mg/kg)	17C (mg/kg)	17D (mg/kg)	18A (mg/kg)	18B (mg/kg)	MDL (mg/kg)
Aluminum	54000	51900	50200	66400	67700	200
Antimony (a)	2 53	2.61	2 35	3 30	2 87	0 04
Arsenic (d)	7	7	7	9	8	2
Barium	231	212	219	190	219	1
Beryllium	4 5	5 6	4.8	4 7	4 1	0 2
Boron	261	252	282	243	250	8
Bromine (c)	NS	6 52	6 10	4 97	NS	0.5
Cadmium (e)	0 8	0 4	ND	ND	ND	0 4
Calcium	2700	2100	2500	1700	2200	400
Cobalt	ND	ND	ND	ND	ND	4
Copper	19	15	14	14	24	8
Iron	17300	15100	15300	24900	24200	30
Lanthanum	51	53	54	47	52	6
Lead (e)	445	323	319	442	370	2
Lithium	28	26	25	33	37	4
Magnesium	1160	1110	1120	1040	1250	70
Manganese	227	220	212	124	146	3
Phosphorus	1170	1060	980	760	1040	20
Scandium	5 4	5 0	5 0	6 8	7 2	0 4
Selenium	ND	ND	ND	ND	ND	50
Silicon	330000	332000	341000	313000	300000	100
Sodium	1100	800	1300	1200	1200	800
Strontium	53 8	49 0	54 6	48 1	53 5	0 8
Sulfur	670	650	560	470	640	70
Tin (b)	12	9	8	9	8	2
Titanium	4210	4070	3980	3890	4120	20
Vanadium	50	47	47	64	70	4
Yttrium	27	27	28	24	26	2
Zinc	300	230	120	90	130	20

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**21. Results of Bulk Elemental Analysis of Soil Litter in the Westgate Trailer Park (continued)**

Analyses by ICP-OES on KOH fusions except as noted  
 (a) Analyses by ICP-MS on HCl digestions (d) Analyses by Hyd Gen / ICP-OES on KOH fusions  
 (b) Analyses by Hyd Gen / ICP-MS on KOH fusions (e) Analyses by ICP-MS on HNO<sub>3</sub> digestions  
 (c) Analyses by INAA

Element	18C (mg/kg)	18D (mg/kg)	19A (mg/kg)	19B (mg/kg)	19C (mg/kg)	MDL (mg/kg)
Aluminum	69500	58100	58400	31000	53800	200
Antimony (a)	3 75	2 82	2 03	1 76	1 93	0 04
Arsenic (d)	9	8	7	3	6	2
Barium	208	186	244	165	229	1
Beryllium	5 8	5 5	6 5	2 5	6 1	0.2
Boron	268	302	288	162	291	8
Bromine (c)	5 94	NS	NS	6 19	NS	0 5
Cadmium (e)	ND	ND	0 4	ND	ND	0 4
Calcium	1700	2200	2300	10600	5200	400
Cobalt	ND	ND	ND	ND	ND	4
Copper	14	14	27	10	15	8
Iron	24100	18900	23500	12200	21700	30
Lanthanum	52	52	61	46	85	6
Lead (e)	471	411	504	287	423	2
Lithium	34	27	42	17	29	4
Magnesium	1180	1130	1370	2270	2250	70
Manganese	118	148	296	175	228	3
Phosphorus	770	890	900	620	720	20
Scandium	6 7	6 1	6 6	3.7	5 9	0 4
Selenium	ND	ND	ND	ND	ND	50
Silicon	330000	321000	364000	373000	354000	100
Sodium	1300	1000	1300	2700	2200	800
Strontium	52 8	47 4	60 8	52.0	56 4	0 8
Sulfur	550	600	190	410	330	70
Tin (b)	9	9	14	8	11	2
Titanium	4020	3700	3560	1970	3540	20
Vanadium	62	56	60	31	63	4
Yttrium	25	26	31	24	39	2
Zinc	90	130	160	100	130	20

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**2.1. Results of Bulk Elemental Analysis of Soil Litter in the Westgate Trailer Park (continued)**

Analyses by ICP-OES on KOH fusions except as noted  
 (a) Analyses by ICP-MS on HCl digestions (d) Analyses by Hyd Gen / ICP-OES on KOH fusions  
 (b) Analyses by Hyd Gen / ICP-MS on KOH fusions (e) Analyses by ICP-MS on HNO<sub>3</sub> digestions  
 (c) Analyses by INAA

Element	19D (mg/kg)	20A (mg/kg)	20B (mg/kg)	20C (mg/kg)	20D (mg/kg)	MDL (mg/kg)
Aluminum	53500	60100	68500	50300	52200	200
Antimony (a)	2 03	3.07	2.47	2.19	2 63	0 04
Arsenic (d)	7	12	10	10	13	2
Barium	225	293	267	345	275	1
Beryllium	5 8	8 5	4 1	8 8	4 8	0 2
Boron	321	258	230	300	307	8
Bromine (c)	6.29	NS	6 50	5 25	5 26	0 5
Cadmium (e)	ND	0 5	ND	0 4	0 6	0 4
Calcium	1900	1800	2100	2500	1800	400
Cobalt	ND	ND	ND	ND	ND	4
Copper	17	33	20	29	26	8
Iron	24000	23400	24300	16800	20000	30
Lanthanum	67	57	56	59	62	6
Lead (e)	418	502	485	488	522	2
Lithium	29	31	33	29	28	4
Magnesium	1130	1060	1150	1110	1140	70
Manganese	233	378	298	511	420	3
Phosphorus	880	1170	1160	1500	970	20
Scandium	5 5	6 7	7 0	5 2	5 7	0 4
Selenium	ND	ND	ND	ND	ND	50
Salicon	369000	344000	316000	336000	348000	100
Sodium	1800	ND	ND	800	ND	800
Strontium	54 7	65 5	65 3	82 1	59 7	0 8
Sulfur	430	490	570	500	550	70
Tin (b)	12	35	26	23	23	2
Titanium	3500	3750	3940	3470	3610	20
Vanadium	49	67	70	50	49	4
Yttrium	31	27	23	27	32	2
Zinc	110	210	140	250	180	20

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2.2. Results of Bulk Elemental Analysis of "Upper" Mineral Soil in the Trailer Park

Analyses by ICP-OES on KOH fusions

Element	02C (mg/kg)	05D (mg/kg)	08C (mg/kg)	10C (mg/kg)	16B (mg/kg)	MDL (mg/kg)
Aluminum	98500	40900	72000	42200	52200	100
Antimony	ND	ND	ND	ND	ND	50
Arsenic	ND	ND	ND	ND	ND	40
Barium	180	90	270	170	150	10
Beryllium	ND	ND	ND	ND	ND	6
Boron	98	386	197	185	321	6
Cadmium	ND	ND	ND	ND	ND	10
Calcium	1800	1300	3000	29900	600	200
Cobalt	4	9	ND	ND	ND	3
Copper	27	14	27	14	14	5
Iron	41000	13000	24000	16000	18000	1000
Lanthanum	33	44	46	41	45	5
Lead	320	1900	1980	930	240	30
Lithium	31	20	37	22	31	2
Magnesium	1100	1010	1630	4160	970	30
Manganese	132	120	234	146	137	4
Phosphorus	520	660	980	560	540	20
Scandium	12 1	4 2	7 5	4 8	5 4	0 4
Selenium	ND	ND	ND	ND	ND	100
Silicon	272000	361000	287000	325000	360000	200
Sodium	800	600	3700	1400	500	400
Strontium	29	23	68	69	32	3
Sulfur	250	330	720	450	140	70
Tin	ND	ND	ND	ND	ND	50
Titanium	4560	2830	4540	2670	3710	3
Vanadium	110	40	70	40	60	10
Yttrium	20	31	27	23	27	1
Zinc	60	110	130	250	150	10

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2.2. Results of Bulk Elemental Analysis of "Upper" Mineral Soil in the Trailer Park (continued)

Analyses by ICP-OES on KOH fusions

Element	17A (mg/kg)	19B (mg/kg)	MDL (mg/kg)
Aluminum	53100	54200	100
Antimony	ND	ND	50
Arsenic	ND	ND	40
Barium	230	220	10
Beryllium	ND	ND	6
Boron	277	294	6
Cadmium	ND	ND	10
Calcium	2500	3200	200
Cobalt	ND	ND	3
Copper	22	23	5
Iron	17000	19000	1000
Lanthanum	56	52	5
Lead	430	380	30
Lithium	28	36	2
Magnesium	1110	1270	30
Manganese	242	239	4
Phosphorus	1080	810	20
Scandium	5 5	6 1	0.4
Selenium	ND	ND	100
Silicon	358000	347000	200
Sodium	800	900	400
Strontium	52	65	3
Sulfur	470	250	70
Tin	ND	ND	50
Titanium	4270	3060	3
Vanadium	50	50	10
Yttrium	36	28	1
Zinc	270	160	10

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23. Results of Bulk Elemental Analysis of "Lower" Mineral Soil in the Trailer Park

Analyses by ICP-OES on KOH fusions

Element	02C (mg/kg)	05D (mg/kg)	08C (mg/kg)	10C (mg/kg)	16B (mg/kg)	MDL (mg/kg)
Aluminum	74100	39600	59800	60700	52900	100
Antimony	ND	ND	ND	ND	ND	50
Arsenic	ND	ND	ND	ND	ND	40
Barium	180	80	240	190	170	10
Beryllium	ND	ND	ND	ND	11	6
Boron	288	349	379	277	313	6
Cadmium	ND	ND	ND	ND	ND	10
Calcium	1200	400	1300	4000	500	200
Cobalt	ND	ND	ND	3	ND	3
Copper	23	12	17	16	15	5
Iron	28000	14000	19000	21000	18000	1000
Lanthanum	48	46	47	54	57	5
Lead	180	420	1040	510	100	30
Lithium	31	21	33	35	30	2
Magnesium	1190	840	1240	1480	880	30
Manganese	296	88	189	153	151	4
Phosphorus	460	480	590	450	540	20
Scandium	8.4	4	6	6	5	0
Selenium	ND	ND	ND	ND	ND	4
Silicon	326000	379000	342000	347000	374000	100
Sodium	1000	ND	2000	ND	ND	200
Strontium	32	18	66	47	38	400
Sulfur	150	140	270	220	150	3
Tin	ND	ND	ND	ND	ND	70
Titanium	4200	2670	4480	3600	4020	50
Vanadium	80	50	60	60	50	3
Yttrium	31	33	27	29	31	10
Zinc	60	70	80	370	120	1



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2.3. Results of Bulk Elemental Analysis of "Lower" Mineral Soil in the Trailer Park (continued)

Analyses by ICP-OES on KOH fusions

Element	17A (mg/kg)	19B (mg/kg)	MDL (mg/kg)
Aluminum	50900	56900	100
Antimony	ND	ND	50
Arsenic	ND	ND	40
Barium	210	280	10
Beryllium	ND	ND	6
Boron	213	334	6
Cadmium	ND	ND	10
Cobalt	ND	ND	3
Calcium	1500	2800	200
Copper	17	21	5
Iron	16000	20000	1000
Lanthanum	52	62	5
Lead	250	170	30
Lithium	30	38	2
Magnesium	930	1320	30
Manganese	219	277	4
Phosphorus	850	840	20
Scandium	5 3	6 6	0 4
Selenium	ND	ND	100
Silicon	355000	372000	200
Sodium	700	1000	400
Strontium	46	70	3
Sulfur	240	190	70
Tin	ND	ND	50
Titanium	4000	3810	3
Vanadium	50	60	10
Yttrium	28	28	1
Zinc	170	160	10

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2.4. Results of Bulk Elemental Analysis of Attic Dust in the Trailer Park

Analyses by ICP-OES on KOH fusions except as noted

(a) Analyses by ICP-MS on HCl digestions

(b) Analyses by Hyd Gen / ICP-MS on KOH fusions

(c) Analyses by INAA

Element	96 (mg/kg)	97 (mg/kg)	98 (mg/kg)	MDL (mg/kg)
Aluminum	53300	49600	68200	80
Antimony	105	66 8	21 6	0 3
Arsenic	ND	ND	ND	40
Barium	451	432	584	3
Beryllium	5 0	4.1	4 9	0 2
Boron	147	203	154	7
Bromine	55 1	56 0	74.8	0 5
Cadmium	ND	ND	ND	10
Calcium	42000	40300	28000	500
Cobalt	9	9	12	4
Copper	966	1170	395	3
Iron	22100	22300	29300	30
Lanthanum	39	36	42	5
Lead	26200	15700	4060	2
Lithium	37	34	47	2
Magnesium	11900	11500	14300	50
Manganese	546	507	490	4
Phosphorus	2590	2690	1840	20
Scandium	9 3	8 7	10 4	0 3
Selenium	ND	ND	ND	40
Silicon	154000	141000	182000	200
Silver	1 44	0 99	0 83	0 02
Sodium	5600	5800	6800	200
Strontium	156	149	139	0 4
Sulfur	7400	7400	5400	300
Tin	66	39	21	1
Titanium	4510	3900	5460	20
Vanadium	72	61	89	5
Yttrium	34 0	33 9	31 3	0 5
Zinc	860	838	627	5

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3. EXIDE BATTERY FACILITY

3.1. Results of Bulk Elemental Analysis of Soil Litter at the Exide Battery Facility

Analyses by ICP-OES on KOH fusions except as noted  
 (a) Analyses by ICP-MS on HCl digestions  
 (b) Analyses by Hyd Gen / ICP-MS on KOH fusions  
 (c) Analyses by INAA

Element	33A (mg/kg)	33B (mg/kg)	33C (mg/kg)	33D (mg/kg)	34A (mg/kg)	MDL (mg/kg)
Aluminum	69700	61600	74100	70600	77200	200
Antimony	270	60	330	480	6	2
Arsenic	30	ND	30	30	ND	20
Barium	689	1120	643	228	192	2
Beryllium	4 2	5 6	4 9	4 5	4 2	0 2
Boron	114	123	117	151	88	5
Bromine	10 3	5 55	8 11	7 67	2 49	0 5
Cadmium	ND	ND	ND	ND	ND	10
Calcium	1700	9000	3000	1300	800	200
Cobalt	18	19	16	17	15	5
Copper	76	40	119	202	44	7
Iron	27300	31600	28800	30100	36300	700
Lanthanum	78	111	80	77	58	7
Lead	39100	13600	43100	66600	5300	20
Lithium	67	74	61	42	76	5
Magnesium	5100	7200	4070	2110	4560	40
Manganese	410	359	271	238	162	2
Phosphorus	1500	1770	1560	740	740	20
Scandium	9 8	11 7	10 5	10 3	15 6	0 5
Selenium	ND	ND	ND	ND	ND	40
Silicon	247000	216000	263000	259000	286000	600
Sodium	1000	2600	2100	700	300	300
Strontium	180	318	167	47 4	29 2	0 7
Sulfur	820	590	780	730	210	60
Tin	224	61	269	307	20	2
Titanium	3410	3950	3510	3030	4700	1
Vanadium	61	76	66	59	108	3
Yttrium	26 2	32 1	41 2	26 4	33 7	0.9
Zinc	270	171	430	328	192	7

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3.1. Results of Bulk Elemental Analysis of Soil Litter at the Exide Battery Facility (continued)

Analyses by ICP-OES on KOH fusions except as noted

(a) Analyses by ICP-MS on HCl digestions

(b) Analyses by Hyd Gen / ICP-MS on KOH fusions

(c) Analyses by INAA

Element	34B (mg/kg)	34C (mg/kg)	34D (mg/kg)	35A (mg/kg)	35B (mg/kg)	MDL (mg/kg)
Aluminum	99700	82500	89200	91100	78400	200
Antimony	8	7	12	34	26	2
Arsenic	ND	ND	ND	ND	ND	20
Barium	198	241	353	409	318	2
Beryllium	6 1	4 5	4 8	5 2	5 1	0 2
Boron	71	284	103	184	205	5
Bromine	2 59	2 75	5 45	5 28	5 87	0 5
Cadmium	ND	ND	ND	ND	ND	10
Calcium	1200	900	1500	1800	1400	200
Cobalt	23	21	13	22	16	5
Copper	43	40	38	27	20	7
Iron	47200	35200	35700	28000	27700	700
Lanthanum	60	71	91	85	76	7
Lead	7590	3470	5730	2390	2030	20
Lithium	90	80	71	63	53	5
Magnesium	4470	4240	3650	3940	2890	40
Manganese	321	279	226	284	247	2
Phosphorus	870	690	1110	850	770	20
Scandium	15.9	14 6	14 7	11 6	10 1	0.5
Selenium	ND	ND	ND	ND	ND	40
Silicon	237000	306000	222000	274000	294000	600
Sodium	400	800	400	1300	500	300
Strontium	23 1	45 9	96 7	114	89.0	0 7
Sulfur	240	150	480	300	370	60
Tin	17	19	24	38	61	2
Titanium	5010	4780	4730	3620	3990	1
Vanadium	127	100	86	66	64	3
Yttrium	33 3	40 2	28 8	24 3	28 4	0 9
Zinc	344	167	177	447	308	7

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3.1. Results of Bulk Elemental Analysis of Soil Litter at the Exide Battery Facility (continued)

Analyses by ICP-OES on KOH fusions except as noted  
 (a) Analyses by ICP-MS on HCl digestions  
 (b) Analyses by Hyd Gen / ICP-MS on KOH fusions  
 (c) Analyses by INAA

Element	35C (mg/kg)	35D (mg/kg)	MDL (mg/kg)
Aluminum	91900	61200	200
Antimony	19	9	2
Arsenic	ND	ND	20
Barium	370	205	2
Beryllium	4	3	0
Boron	119	104	5
Bromine	6	2	0
Cadmium	87	21	5
Calcium	ND	ND	10
Cobalt	8200	2300	200
Copper	16	27	5
Iron	19	19	7
Lanthanum	28600	17400	700
Lead	64	36	7
Lithium	2600	1260	20
Magnesium	68	58	5
Manganese	4500	2450	40
Phosphorus	305	391	2
Scandium	810	490	20
Selenium	10.2	7	0.5
Silicon	ND	ND	40
Sodium	276000	343000	600
Strontium	7900	2800	300
Sulfur	133	57	0
Tin	380	220	7
Titanium	31	22	60
Vanadium	3720	1990	2
Yttrium	59	42	1
Zinc	24	11	3
	265	134	0
			9
			7

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3.2. Results of Bulk Elemental Analysis of Process Material and Dust at the Exide Battery Facility

Analyses by ICP-OES on KOH fusions except as noted

(a) Analyses by ICP-MS on HCl digestions

(b) Analyses by Hyd Gen / ICP-MS on KOH fusions

(c) Analyses by INAA

Element	21 (mg/kg)	22 (mg/kg)	23 (mg/kg)	24 (mg/kg)	25 (mg/kg)	MDL (mg/kg)
Aluminum	50	2640	1010	ND	20100	30
Antimony	271	231	616	ND	3240	7
Arsenic	ND	30	ND	ND	410	20
Barium	1690	44	ND	ND	212	4
Beryllium	ND	ND	ND	ND	0 4	0 3
Boron	ND	ND	ND	ND	89	7
Bromine	10 0	36.7	21 1	14 7	109	0 5
Cadmium	ND	10	ND	ND	480	10
Calcium	ND	3700	2100	ND	5900	300
Cobalt	ND	ND	ND	ND	11	3
Copper	ND	80	ND	ND	460	40
Iron	3710	4300	429	46	14600	5
Lanthanum	ND	ND	ND	ND	12	8
Lead	808000	818000	784000	853000	132000	60
Lithium	ND	ND	7	ND	17	4
Magnesium	ND	330	ND	ND	2080	70
Manganese	ND	70	ND	ND	260	40
Phosphorus	20	100	ND	ND	32800	20
Scandium	ND	ND	ND	ND	1 4	0 4
Selenium	ND	ND	ND	ND	60	30
Silicon	170	5600	1480	90	75200	50
Sodium	2800	3300	3200	ND	19800	400
Strontium	18	9	4	ND	74	2
Sulfur	16700	1590	340	ND	7960	50
Tin	88	355	17	56	584	2
Titanium	ND	240	60	ND	2300	20
Vanadium	ND	ND	ND	ND	9	3
Yttrium	ND	1 2	ND	ND	7 9	0 7
Zinc	ND	550	ND	ND	9270	20

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### 3.2. Results of Bulk Elemental Analysis of Process Material and Dust at the Exide Battery Facility (continued)

Analyses by ICP-OES on KOH fusions except as noted

(a) Analyses by ICP-MS on HCl digestions

(b) Analyses by Hyd Gen / ICP-MS on KOH fusions

(c) Analyses by INAA

Element	26 (mg/kg)	27 (mg/kg)	28 (mg/kg)	29 (mg/kg)	30 (mg/kg)	MDL (mg/kg)
Aluminum	17200	20700	120	60	50	30
Antimony (a)	2250	3620	38	67	22	7
Arsenic	260	430	30	ND	ND	20
Barium	509	333	5770	52100	241	4
Beryllium	0 4	0 3	ND	4 7	ND	0 3
Boron	53	131	ND	ND	ND	7
Bromine (c)	162	197	29 1	24.7	10 5	0 5
Cadmium	130	230	ND	ND	ND	10
Calcium	10300	6400	2100	ND	ND	300
Cobalt	14	17	ND	ND	ND	3
Copper	280	770	ND	ND	ND	40
Iron	18800	15700	5840	726	922	5
Lanthanum	11	12	ND	ND	ND	8
Lead (a)	294000	155000	816000	694000	848000	60
Lithium	9	19	ND	4	ND	4
Magnesium	1870	2190	90	ND	ND	70
Manganese	180	220	ND	ND	ND	40
Phosphorus	23100	5780	120	20	30	20
Scandium	1 4	1 4	ND	ND	ND	0 4
Selenium	40	150	ND	ND	ND	30
Silicon	56800	75800	580	190	320	50
Sodium	11600	19900	3800	2000	3400	400
Strontium	57	77	76	520	3	2
Sulfur	12900	11200	6970	16000	1590	50
Tin	999	2490	68	35	21	2
Titanium	2920	1990	70	ND	50	20
Vanadium	9	8	ND	ND	ND	3
Yttrium	6.5	9 5	ND	ND	ND	0 7
Zinc	1140	1580	60	40	60	20

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3.2. Results of Bulk Elemental Analysis of Process Material and Dust at the Exide Battery Facility (continued)

Analyses by ICP-OES on KOH fusions except as noted

(a) Analyses by ICP-MS on HCl digestions

(b) Analyses by Hyd Gen / ICP-MS on KOH fusions

(c) Analyses by INAA

Element	31 (mg/kg)	32 (mg/kg)	36 (mg/kg)	37 (mg/kg)	38 (mg/kg)	MDL (mg/kg)
Aluminum	370	470	71300	68800	58200	30
Antimony	544	13	87	4260	607	7
Arsenic	60	70	ND	560	60	20
Barium	4050	2770	403	936	599	4
Beryllium	ND	ND	1 5	3 8	2 1	0 3
Boron	ND	ND	11	42	55	7
Bromine	192	621	7 76	17 3	47 2	0 5
Cadmium	ND	ND	ND	40	ND	10
Calcium	700	1100	19800	3800	11100	300
Cobalt	ND	ND	4	7	4	3
Copper	50	ND	100	810	150	40
Iron	584	994	22000	34900	31300	5
Lanthanum	ND	ND	19	94	46	8
Lead	823000	821000	17200	273000	90500	60
Lithium	ND	ND	21	36	30	4
Magnesium	ND	90	4230	2940	3000	70
Manganese	ND	ND	500	310	330	40
Phosphorus	210	130	870	2930	890	20
Scandium	ND	ND	9.2	8.4	6 2	0 4
Selenium	ND	ND	ND	150	ND	30
Silicon	880	1460	313000	118000	239000	50
Sodium	800	3900	24900	2600	13200	400
Strontium	49	33	110	178	130	2
Sulfur	11800	13600	400	1880	3250	50
Tin	716	852	113	5920	335	2
Titanium	440	360	1800	3440	2730	20
Vanadium	ND	ND	30	48	39	3
Yttrium	ND	1 3	22.0	25 2	19 9	0.7
Zinc	60	80	410	1600	510	20



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3.2. Results of Bulk Elemental Analysis of Process Material and Dust at the Exide Battery Facility (continued)

Analyses by ICP-OES on KOH fusions except as noted  
 (a) Analyses by ICP-MS on HCl digestions  
 (b) Analyses by Hyd Gen / ICP-MS on KOH fusions  
 (c) Analyses by INAA

Element	39 (mg/kg)	40 (mg/kg)	90 (mg/kg)	MDL (mg/kg)
Aluminum	54300	30600	320	30
Antimony (a)	389	1000	1090	7
Arsenic	30	90	100	20
Barium	406	574	615	4
Beryllium	2 7	1 3	ND	0 3
Boron	43	65	ND	7
Bromine (c)	21.7	162	2490	0.5
Cadmium	ND	ND	10	10
Calcium	11100	4000	1200	300
Cobalt	7	5	ND	3
Copper	130	680	60	40
Iron	24200	18200	5460	5
Lanthanum	47	28	ND	8
Lead	181000	417000	741000	60
Lithium	24	14	ND	4
Magnesium	2620	1340	ND	70
Manganese	280	170	50	40
Phosphorus	2150	2150	320	20
Scandium	6 5	3 5	ND	0 4
Selenium	ND	ND	ND	30
Silicon	203000	107000	5410	50
Sodium	10600	2400	500	400
Strontium	86	47	7	2
Sulfur	3170	15800	13600	50
Tin	345	593	2210	2
Titanium	2540	2370	50	20
Vanadium	42	36	ND	3
Yttrium	34 0	22 7	ND	0 7
Zinc	840	600	3040	20

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4. WOODED AREAS

4.1. Results of Bulk Elemental Analysis of Soil Litter in the Wooded Areas

Analyses by ICP-OES on KOH fusions except as noted

(a) Analyses by ICP-MS on HCl digestions

(b) Analyses by Hyd Gen / ICP-MS on KOH fusions

(c) Analyses by INAA

Element	61A (mg/kg)	61B (mg/kg)	61C (mg/kg)	61D (mg/kg)	62A (mg/kg)	MDL (mg/kg)
Aluminum	61500	80800	63100	101000	106000	80
Antimony	8.4	13.6	5.9	7.1	17.7	0.3
Arsenic	ND	ND	ND	ND	ND	40
Barium	141	172	183	193	281	3
Beryllium	2.2	2.7	4.0	3.8	3.3	0.2
Boron	104	58	106	69	86	7
Bromine	NS	NS	NS	8.51	6.67	0.5
Cadmium	ND	ND	ND	ND	ND	10
Calcium	1300	1800	2700	ND	1800	500
Cobalt	26	16	34	14	12	4
Copper	21	32	20	27	36	3
Iron	24100	29000	22400	28300	39500	30
Lanthanum	50	49	35	40	58	5
Lead	925	1710	692	1120	2270	2
Lithium	33	41	41	61	58	2
Magnesium	1020	1380	1700	1200	2100	50
Manganese	139	164	138	165	170	4
Phosphorus	700	790	610	530	750	20
Scandium	8.4	10.4	7.5	10.5	12.5	0.3
Selenium	ND	ND	ND	ND	ND	70
Silicon	220000	144000	250000	269000	232000	300
Silver	0.20	0.27	0.16	0.19	0.32	0.02
Sodium	400	700	3900	600	2400	200
Strontium	33.4	42.1	47.4	39.0	64.7	0.4
Sulfur	800	1200	700	300	1600	300
Tin	9	13	7	11	18	1
Titanium	2800	3030	2860	4690	4090	20
Vanadium	54	66	55	86	88	5
Yttrium	20.6	19.1	21.5	19.5	19.5	0.5
Zinc	81	97	78	72	95	5

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4.1. Results of Bulk Elemental Analysis of Soil Litter in the Wooded Areas (continued)

Analyses by ICP-OES on KOH fusions except as noted  
(a) Analyses by ICP-MS on HCl digestions  
(b) Analyses by Hyd Gen / ICP-MS on KOH fusions  
(c) Analyses by INAA

Element	62B (mg/kg)	62C (mg/kg)	62D (mg/kg)	63A (mg/kg)	63B (mg/kg)	MDL (mg/kg)
Aluminum	125000	69000	102000	52400	53500	80
Antimony (a)	18.1	13.4	30.7	10.9	4.0	0.3
Arsenic	ND	ND	ND	ND	ND	40
Barium	307	221	265	138	141	3
Beryllium	3.6	3.3	2.7	2.3	2.9	0.2
Boron	64	92	19	108	151	7
Bromine (c)	NS	4.96	11.6	NS	6.77	0.5
Cadmium	ND	ND	ND	ND	ND	10
Calcium	1900	1700	3300	1100	500	500
Cobalt	15	18	8	15	7	4
Copper	38	26	40	12	13	3
Iron	42000	27700	40900	15800	16100	30
Lanthanum	67	37	59	39	49	5
Lead	2070	1830	3860	1170	644	2
Lithium	64	45	51	30	36	2
Magnesium	2350	1620	2310	850	810	50
Manganese	190	223	293	107	111	4
Phosphorus	730	610	980	460	390	20
Scandium	13.3	8.6	12.0	5.4	6.4	0.3
Selenium	ND	ND	ND	ND	ND	70
Silicon	212000	301000	135000	273000	341000	300
Silver (a)	0.38	0.25	0.46	0.13	0.11	0.02
Sodium	2800	2200	2300	700	400	200
Strontium	70.0	50.3	57.9	32.4	33.7	0.4
Sulfur	1300	1100	2600	600	300	300
Tin	18	12	26	11	6	1
Titanium	4060	2760	4150	2560	2700	20
Vanadium	92	61	80	46	42	5
Yttrium	19.7	15.8	15.4	26.2	29.8	0.5
Zinc	95	78	122	40	31	5

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4.1. Results of Bulk Elemental Analysis of Soil Litter in the Wooded Areas (continued)

Analyses by ICP-OES on KOH fusions except as noted

(a) Analyses by ICP-MS on HCl digestions

(b) Analyses by Hyd Gen / ICP-MS on KOH fusions

(c) Analyses by INAA

Element	63C (mg/kg)	63D (mg/kg)	64A (mg/kg)	64B (mg/kg)	64C (mg/kg)	MDL (mg/kg)
Aluminum	67200	55000	61300	73300	69200	80
Antimony	6.0	5.9	28.3	22.9	25.3	0.3
Arsenic	ND	ND	ND	ND	ND	40
Barium	171	151	128	146	147	3
Beryllium	4.8	2.5	2.7	3.6	3.6	0.2
Boron	121	129	107	142	197	7
Bromine	5.75	NS	NS	7.91	NS	0.5
Cadmium	ND	ND	ND	ND	ND	10
Calcium	500	600	3000	1600	1600	500
Cobalt	16	18	19	14	22	4
Copper	15	11	20	21	25	3
Iron	19200	14100	22900	25800	26500	30
Lanthanum	60	48	35	39	57	5
Lead	844	659	3300	2810	2680	2
Lithium	45	35	27	40	41	2
Magnesium	910	780	1070	1310	1270	50
Manganese	82	131	465	243	279	4
Phosphorus	480	460	800	680	800	20
Scandium	6.8	5.4	7.5	9.0	10.1	0.3
Selenium	ND	ND	ND	ND	ND	70
Silicon	301000	328000	194000	210000	242000	300
Silver	0.13	0.11	0.28	0.18	0.23	0.02
Sodium	400	300	400	800	500	200
Strontium	42.0	34.5	28.9	31.2	30.9	0.4
Sulfur	400	400	1100	800	900	300
Tin	10	9	19	18	20	1
Titanium	2950	2580	2120	2870	3050	20
Vanadium	52	44	51	60	63	5
Yttrium	37.0	35.6	18.7	19.1	31.0	0.5
Zinc	35	34	148	73	133	5

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4.1. Results of Bulk Elemental Analysis of Soil Litter in the Wooded Areas (continued)

Analyses by ICP-OES on KOH fusions except as noted

(a) Analyses by ICP-MS on HCl digestions

(b) Analyses by Hyd Gen / ICP-MS on KOH fusions

(c) Analyses by INAA

Element	64D (mg/kg)	65A (mg/kg)	65B (mg/kg)	65C (mg/kg)	65D (mg/kg)	MDL (mg/kg)
Aluminum	83200	87400	81000	82300	88800	80
Antimony	18 8	NA	13 0	13 4	21 3	0 3
Arsenic	ND	ND	ND	ND	ND	40
Barium	140	176	223	191	150	3
Beryllium	5 9	6 7	3 7	3.5	4 2	0.2
Boron	133	208	184	205	132	7
Bromine	9.20	NS	4 96	NS	NS	0 5
Cadmium	ND	ND	ND	ND	ND	10
Calcium	1400	1600	3400	2700	2800	500
Cobalt	17	27	16	25	26	4
Copper	21	21	25	23	22	3
Iron	29100	32700	31900	31600	33500	30
Lanthanum	44	48	52	48	38	5
Lead	2120	577	1160	1050	2340	2
Lithium	43	52	46	48	42	2
Magnesium	1170	1890	1550	1760	1400	50
Manganese	273	386	1050	806	882	4
Phosphorus	700	580	810	750	890	20
Scandium	9 9	10 4	10 1	9 8	10 6	0 3
Selenium	ND	ND	ND	ND	ND	70
Silicon	249000	310000	238000	253000	232000	300
Silver	0 22	ND	0 24	0 21	0 27	0 02
Sodium	600	700	300	800	700	200
Strontium	29.7	36 5	59 0	46.6	37 8	0 4
Sulfur	900	400	700	700	900	300
Tin	16	9	14	12	19	1
Titanium	3210	3680	3680	3610	3360	20
Vanadium	69	83	72	76	71	5
Yttrium	25 8	26 9	25 0	31 9	19 9	0 5
Zinc	111	78	99	88	83	5

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4.1. Results of Bulk Elemental Analysis of Soil Litter in the Wooded Areas (continued)

Analyses by ICP-OES on KOH fusions except as noted

(a) Analyses by ICP-MS on HCl digestions

(b) Analyses by Hyd Gen / ICP-MS on KOH fusions

(c) Analyses by INAA

Element	66A (mg/kg)	66B (mg/kg)	66C (mg/kg)	66D (mg/kg)	67A (mg/kg)	MDL (mg/kg)
Aluminum	94700	98700	88600	95900	81100	80
Antimony	15 0	7.8	20 0	6.4	7.6	0 3
Arsenic	ND	ND	ND	ND	ND	40
Barium	191	134	177	145	287	3
Beryllium	3 4	4 7	3 4	5 1	5.0	0 2
Boron	126	170	125	188	245	7
Bromine	1 74	NS	NS	5 11	4 36	0 5
Cadmium	ND	ND	ND	ND	ND	10
Calcium	3500	1500	4700	1600	2000	500
Cobalt	23	24	22	29	25	4
Copper	29	27	32	26	24	3
Iron	35000	35300	32900	36100	31100	30
Lanthanum	42	36	42	43	65	5
Lead	1910	719	1920	706	677	2
Lithium	48	51	44	51	52	2
Magnesium	1830	1580	1630	1550	1940	50
Manganese	692	262	660	437	400	4
Phosphorus	820	620	990	610	840	20
Scandium	11 3	11 2	10 9	11 8	11 5	0 3
Selenium	ND	ND	ND	ND	ND	70
Silicon	237000	262000	197000	271000	296000	300
Silver	0 26	0 18	0.25	0.23	0 21	0 02
Sodium	1600	800	1400	800	1100	200
Strontium	44 4	31 5	40.8	28 3	106	0 4
Sulfur	1000	600	1100	500	500	300
Tin	13	9	15	8	10	1
Titanium	3930	3980	3680	3930	3410	20
Vanadium	85	88	82	89	74	5
Yttrium	20 4	18.9	18 9	22 9	34 1	0 5
Zinc	177	85	190	91	226	5

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4.1. Results of Bulk Elemental Analysis of Soil Litter in the Wooded Areas (continued)

Analyses by ICP-OES on KOH fusions except as noted

(a) Analyses by ICP-MS on HCl digestions

(b) Analyses by Hyd Gen / ICP-MS on KOH fusions

(c) Analyses by INAA

Element	67B (mg/kg)	67C (mg/kg)	67D (mg/kg)	71A (mg/kg)	71B (mg/kg)	MDL (mg/kg)
Aluminum	89200	81700	82200	22200	95300	80
Antimony	9 9	13 6	6 2	7 5	10 6	0 3
Arsenic	ND	ND	ND	ND	ND	40
Barium	182	257	163	91	187	3
Beryllium	4 3	4 2	5 0	0 9	3 9	0 2
Boron	224	194	353	49	90	7
Bromine	5 10	5 13	NS	NS	NS	0 5
Cadmium	ND	ND	ND	ND	ND	10
Calcium	2700	2400	2100	3700	1400	500
Cobalt	21	22	17	17	26	4
Copper	31	28	25	12	31	3
Iron	36700	32900	35400	6750	31600	30
Lanthanum	44	53	58	14	62	5
Lead	948	1710	686	1260	1210	2
Lithium	61	50	55	13	52	2
Magnesium	2530	2390	2130	730	1610	50
Manganese	339	266	334	640	244	4
Phosphorus	700	670	720	820	770	20
Scandium	12.2	11 0	11 6	2.3	12 0	0 3
Selenium	ND	ND	ND	ND	ND	70
Silicon	272000	292000	280000	107000	216000	300
Silver	0 23	0 19	0.17	0.20	0.16	0 02
Sodium	1500	2800	900	700	1100	200
Strontium	37 6	57 3	27.5	24 8	47 4	0 4
Sulfur	700	1100	500	1600	900	300
Tin	9	11	9	6	14	1
Titanium	4200	3490	4140	1070	4030	20
Vanadium	89	80	94	19	82	5
Yttrium	24 1	22.9	33 3	9 8	24 0	0 5
Zinc	217	131	190	77	67	5

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4 1. Results of Bulk Elemental Analysis of Soil Litter in the Wooded Areas (continued)

Analyses by ICP-OES on KOH fusions except as noted  
(a) Analyses by ICP-MS on HCl digestions  
(b) Analyses by Hyd Gen / ICP-MS on KOH fusions  
(c) Analyses by INAA

Element	71C (mg/kg)	71D (mg/kg)	72A (mg/kg)	72B (mg/kg)	72C (mg/kg)	MDL (mg/kg)
Aluminum	89700	94600	126000	66300	92200	80
Antimony	5 1	4 2	7.0	1 1	6 7	0 3
Arsenic	ND	ND	ND	ND	ND	40
Barium	174	178	217	100	161	3
Beryllium	3.1	3.7	4.2	2 5	3 7	0 2
Boron	86	122	76	171	137	7
Bromine	1 58	5 22	9.78	NS	NS	0 5
Cadmium	ND	ND	ND	ND	ND	10
Calcium	3100	700	900	800	600	500
Cobalt	22	14	19	20	24	4
Copper	21	23	34	12	26	3
Iron	24700	25100	38300	17700	25400	30
Lanthanum	38	48	66	33	55	5
Lead	715	624	1000	101	921	2
Lithium	44	65	55	34	46	2
Magnesium	1210	1880	1650	750	1090	50
Manganese	1150	95	160	176	159	4
Phosphorus	760	490	800	320	540	20
Scandium	9.1	10 7	14 9	6 5	10 5	0.3
Selenium	ND	ND	ND	ND	ND	70
Silicon	216000	281000	191000	276000	243000	300
Silver	0 26	0 21	0 18	0 11	0.15	0 02
Sodium	400	1900	600	ND	300	200
Strontium	43.8	38 0	56 5	26.8	44 5	0 4
Sulfur	700	400	700	300	500	300
Tin	10	9	17	5	10	1
Titanium	4630	3940	4720	3120	3630	20
Vanadium	79	81	101	62	77	5
Yttrium	22 7	26 0	29 3	26.0	25 2	0 5
Zinc	64	130	78	37	51	5



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4 1. Results of Bulk Elemental Analysis of Soil Litter in the Wooded Areas (continued)

Analyses by ICP-OES on KOH fusions except as noted  
(a) Analyses by ICP-MS on HCl digestions  
(b) Analyses by Hyd Gen / ICP-MS on KOH fusions  
(c) Analyses by INAA

Element	72D (mg/kg)	73A (mg/kg)	73B (mg/kg)	73C (mg/kg)	73D (mg/kg)	MDL (mg/kg)
Aluminum	90400	58600	48200	14200	71700	80
Antimony (a)	1.9	3 8	2 7	2 0	8 0	0 3
Arsenic	ND	ND	ND	ND	ND	40
Barium	121	151	148	84	193	3
Beryllium	2 9	2 8	2 4	0 6	3 2	0 2
Boron	139	113	126	30	105	7
Bromine (c)	5.07	6 00	6 92	NS	NS	0.5
Cadmium	ND	ND	ND	ND	ND	10
Calcium	400	1000	700	1200	1100	500
Cobalt	19	21	8	11	19	4
Copper	16	13	12	9	18	3
Iron	25400	15300	11600	4480	21800	30
Lanthanum	34	38	52	6	47	5
Lead	172	480	408	138	1020	2
Lithium	48	35	26	8	36	2
Magnesium	750	960	720	370	900	50
Manganese	82	134	82	84	108	4
Phosphorus	360	470	430	260	630	20
Scandium	9 3	6 0	5 1	1.5	7.5	0 3
Selenium	ND	ND	ND	ND	ND	70
Silicon	289000	308000	292000	62200	214000	300
Silver (a)	0.12	0 12	0 10	0 07	0 16	0 02
Sodium	ND	700	400	300	500	200
Strontium	30.2	35 2	36 1	24 3	50 2	0.4
Sulfur	300	600	500	600	800	300
Tin	9	6	5	2	14	1
Titanium	3990	3130	3210	710	4540	20
Vanadium	80	50	44	11	64	5
Yttrium	22.4	23 6	25 4	4.2	22 8	0 5
Zinc	33	35	25	39	48	5

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4.1. Results of Bulk Elemental Analysis of Soil Litter in the Wooded Areas (continued)

Analyses by ICP-OES on KOH fusions except as noted  
 (a) Analyses by ICP-MS on HCl digestions  
 (b) Analyses by Hyd Gen / ICP-MS on KOH fusions  
 (c) Analyses by INAA

Element	74A (mg/kg)	74B (mg/kg)	74C (mg/kg)	74D (mg/kg)	75A (mg/kg)	MDL (mg/kg)
Aluminum	24800	43100	27600	67300	28300	80
Antimony	2 3	1 0	2 4	4 1	11 0	0 3
Arsenic	ND	ND	ND	ND	ND	40
Barium	93	98	107	145	75	3
Beryllium	1 7	2 2	1 3	3 1	0 8	0 2
Boron	112	154	77	119	37	7
Bromine	NS	2 64	NS	4 71	NS	0 5
Cadmium	ND	ND	ND	ND	ND	10
Calcium	2000	600	2800	700	5400	500
Cobalt	75	22	55	14	22	4
Copper	11	6	11	36	10	3
Iron	15300	6140	3890	12100	6830	30
Lanthanum	13	28	14	35	9	5
Lead	410	114	410	498	1640	2
Lithium	16	30	20	40	16	2
Magnesium	580	600	610	910	560	50
Manganese	951	186	1100	242	331	4
Phosphorus	600	230	520	460	690	20
Scandium	2 0	3 7	2 4	6 2	2 6	0.3
Selenium	ND	ND	ND	ND	ND	70
Silicon	264000	368000	270000	308000	117000	300
Silver	0 11	0 05	0 10	0 09	0.18	0.02
Sodium	ND	300	200	500	ND	200
Strontium	25 4	22 1	32 9	32 0	36 8	0.4
Sulfur	800	ND	300	500	1200	300
Tin	3	3	3	17	11	1
Titanium	1120	2210	1260	2880	850	20
Vanadium	14	32	21	49	17	5
Yttrium	18.6	25 6	15 4	26 3	8 9	0 5
Zinc	50	19	42	32	41	5

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4.1. Results of Bulk Elemental Analysis of Soil Litter in the Wooded Areas (continued)

Analyses by ICP-OES on KOH fusions except as noted

(a) Analyses by ICP-MS on HCl digestions

(b) Analyses by Hyd Gen / ICP-MS on KOH fusions

(c) Analyses by INAA

Element	75B (mg/kg)	75C (mg/kg)	75D (mg/kg)	76A (mg/kg)	76B (mg/kg)	MDL (mg/kg)
Aluminum	72500	91300	58000	95100	96500	80
Antimony	4 8	4.5	12 2	8 9	16 5	0 3
Arsenic	ND	ND	ND	ND	ND	40
Barium	98	65	143	206	157	3
Beryllium	2 2	1 8	2.5	4 3	3 4	0 2
Boron	98	59	89	142	98	7
Bromine	5 82	NS	17 7	NS	8 60	0 5
Cadmium	ND	ND	ND	ND	ND	10
Calcium	1100	ND	900	2200	2300	500
Cobalt	8	8	7	25	11	4
Copper	11	9	16	26	26	3
Iron	17300	20400	14400	33100	35000	30
Lanthanum	28	23	36	40	36	5
Lead	860	657	1790	1010	1520	2
Lithium	41	45	34	47	46	2
Magnesium	720	500	810	1840	1370	50
Manganese	280	78	109	469	908	4
Phosphorus	360	360	450	700	940	20
Scandium	6.0	6.8	5 8	11.4	11 6	0 3
Selenium	ND	ND	ND	ND	ND	70
Silicon	280000	226000	243000	253000	204000	300
Silver	0.11	0 13	0.14	0 21	0 26	0 02
Sodium	300	ND	600	1500	600	200
Strontium	23 5	14.8	31.0	48 3	36 7	0 4
Sulfur	400	500	700	600	800	300
Tin	7	8	12	11	17	1
Titanium	2970	2320	3470	3580	3750	20
Vanadium	48	44	47	79	82	5
Yttrium	22 7	19 4	59.6	20 4	16 5	0 5
Zinc	31	31	38	88	95	5

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4.1. Results of Bulk Elemental Analysis of Soil Litter in the Wooded Areas (continued)

Analyses by ICP-OES on KOH fusions except as noted

(a) Analyses by ICP-MS on HCl digestions

(b) Analyses by Hyd Gen / ICP-MS on KOH fusions

(c) Analyses by INAA

Element	76C (mg/kg)	76D (mg/kg)	77A (mg/kg)	77B (mg/kg)	77C (mg/kg)	MDL (mg/kg)
Aluminum	117000	111000	79900	134000	57800	80
Antimony	11 0	10 3	4 8	3 3	2.7	0 3
Arsenic	ND	ND	ND	ND	ND	40
Barium	213	205	179	237	107	3
Beryllium	4 8	4 1	4 7	4 4	3.2	0 2
Boron	67	81	207	39	174	7
Bromine	NS	4 98	NS	3 60	2 72	0 5
Cadmium	ND	ND	ND	ND	ND	10
Calcium	1700	1700	1900	700	700	500
Cobalt	19	16	24	7	11	4
Copper	30	32	27	35	16	3
Iron	41900	40900	26400	33400	20400	30
Lanthanum	42	41	46	52	30	5
Lead	1050	1050	893	498	307	2
Lithium	58	58	43	73	38	2
Magnesium	2060	1860	1780	1540	1140	50
Manganese	354	242	260	177	144	4
Phosphorus	800	700	790	740	390	20
Scandium	13 5	13 0	9 6	13.4	7 3	0.3
Selenium	ND	ND	ND	ND	ND	70
Silicon	229000	253000	285000	191000	361000	300
Silver	0 25	0 26	0 21	0 13	0 12	0 02
Sodium	1200	1300	1600	400	600	200
Strontium	40.0	46 0	38 0	50 2	20 9	0 4
Sulfur	700	800	800	500	ND	300
Tin	15	12	8	14	6	1
Titanium	4380	4180	3730	5800	2590	20
Vanadium	99	97	70	101	53	5
Yttrium	18.5	17 3	26 9	23 2	17 6	0 5
Zinc	93	87	136	90	59	5

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**4.1. Results of Bulk Elemental Analysis of Soil Litter in the Wooded Areas (continued)**

Analyses by ICP-OES on KOH fusions except as noted

(a) Analyses by ICP-MS on HCl digestions

(b) Analyses by Hyd Gen / ICP-MS on KOH fusions

(c) Analyses by INAA

Element	77D (mg/kg)	78A (mg/kg)	78B (mg/kg)	78C (mg/kg)	78D (mg/kg)	MDL (mg/kg)
Aluminum	73400	40800	44500	48100	45200	80
Antimony	6 3	1.9	2 6	2 5	2 1	0 3
Arsenic	ND	ND	ND	ND	ND	40
Barium	176	147	164	192	153	3
Beryllium	4 6	3 1	3.8	7.6	2.4	0 2
Boron	217	248	324	262	287	7
Bromine	NS	3 47	NS	3.20	NS	0 5
Cadmium	ND	ND	ND	ND	ND	10
Calcium	1900	1900	1700	2300	1400	500
Cobalt	22	11	15	14	11	4
Copper	26	9	11	12	12	3
Iron	25200	11400	16900	17600	12500	30
Lanthanum	44	37	43	39	36	5
Lead	898	482	366	438	354	2
Lithium	43	22	23	26	25	2
Magnesium	1650	970	1050	980	920	50
Manganese	293	85	85	93	81	4
Phosphorus	750	430	430	490	370	20
Scandium	9.1	4 7	5 3	5 5	5 1	0 3
Selenium	ND	ND	ND	ND	ND	70
Silicon	284000	372000	378000	370000	392000	300
Silver	0.21	0 07	0 08	0 11	0 09	0 02
Sodium	1500	2500	2500	3800	2000	200
Strontium	36.8	38 7	41.5	46.9	37 8	0 4
Sulfur	700	600	400	400	400	300
Tin	8	3	3	4	3	1
Titanium	3450	2410	2750	2520	3030	20
Vanadium	63	36	46	47	42	5
Yttrium	25 5	27 0	33 6	28 4	25 3	0 5
Zinc	124	29	30	33	29	5

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4.1. Results of Bulk Elemental Analysis of Soil Litter in the Wooded Areas (continued)

Analyses by ICP-OES on KOH fusions except as noted

(a) Analyses by ICP-MS on HCl digestions

(b) Analyses by Hyd Gen / ICP-MS on KOH fusions

(c) Analyses by INAA

Element	91A (mg/kg)	91B (mg/kg)	91C (mg/kg)	91D (mg/kg)	92A (mg/kg)	MDL (mg/kg)
Aluminum	82100	73500	79800	87300	63100	80
Antimony	2 5	1.7	1 7	3.2	4.3	0 3
Arsenic	ND	ND	ND	ND	ND	40
Barium	242	198	231	214	137	3
Beryllium	3 8	5.1	4.2	3.1	3 6	0 2
Boron	108	125	165	131	245	7
Bromine	8 11	NS	4.95	NS	NS	0 5
Cadmium	ND	ND	ND	ND	ND	10
Calcium	3200	1800	2300	1900	1000	500
Cobalt	16	33	16	15	15	4
Copper	37	29	28	28	19	3
Iron	27900	21300	26800	35100	20000	30
Lanthanum	42	31	38	42	37	5
Lead	345	224	156	328	971	2
Lithium	46	53	49	49	37	2
Magnesium	1300	1080	1120	1250	1080	50
Manganese	564	583	242	277	190	4
Phosphorus	720	510	540	620	600	20
Scandium	7.9	7 6	9 0	9 4	7.4	0 3
Selenium	ND	ND	ND	ND	ND	70
Silicon	252000	288000	252000	281000	347000	300
Silver	0.13	0.13	0.13	0.19	0 18	0 02
Sodium	600	200	300	400	1000	200
Strontium	62.7	60.9	79.3	60.5	26 5	0 4
Sulfur	700	400	400	600	600	300
Tin	8	7	6	11	6	1
Titanium	4570	3370	4000	4220	3030	20
Vanadium	74	62	75	87	56	5
Yttrium	26 6	19 6	25 4	23 6	21 3	0 5
Zinc	71	46	41	56	66	5

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4.1. Results of Bulk Elemental Analysis of Soil Litter in the Wooded Areas (continued)

Analyses by ICP-OES on KOH fusions except as noted

(a) Analyses by ICP-MS on HCl digestions

(b) Analyses by Hyd Gen / ICP-MS on KOH fusions

(c) Analyses by INAA

Element	92B (mg/kg)	92C (mg/kg)	92D (mg/kg)	93A (mg/kg)	93B (mg/kg)	MDL (mg/kg)
Aluminum	104000	130000	122000	134000	119000	80
Antimony	3.3	4 4	3 4	5 7	6 1	0 3
Arsenic	ND	ND	ND	ND	ND	40
Barium	224	260	369	272	294	3
Beryllium	4 7	5 0	4 7	4 8	4 2	0 2
Boron	103	52	124	57	53	7
Bromine	NS	8.47	6 08	10.3	NS	0.5
Cadmium	ND	ND	ND	ND	ND	10
Calcium	700	1200	1300	700	1200	500
Cobalt	14	11	8	11	18	4
Copper	39	35	36	35	31	3
Iron	37300	36800	37400	43300	38300	30
Lanthanum	71	54	76	54	49	5
Lead	576	763	556	858	1170	2
Lithium	56	77	70	70	64	2
Magnesium	1560	1740	1490	1780	1530	50
Manganese	139	235	211	147	406	4
Phosphorus	790	750	780	720	820	20
Scandium	14 1	14 1	13 6	14 8	13 6	0 3
Selenium	ND	ND	ND	ND	ND	70
Silicon	217000	223000	246000	213000	192000	300
Silver	0 13	0 20	0 25	0 19	0 24	0 02
Sodium	900	700	600	500	400	200
Strontium	27.5	59 7	91.7	66.7	67.8	0 4
Sulfur	800	500	300	400	600	300
Tin	16	15	11	17	17	1
Titanium	4000	5600	5080	7610	6550	20
Vanadium	88	100	103	126	107	5
Yttrium	28 4	23 2	30 6	23.1	21 0	0 5
Zinc	71	92	69	82	96	5

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**4.1. Results of Bulk Elemental Analysis of Soil Litter in the Wooded Areas (continued)**

Analyses by ICP-OES on KOH fusions except as noted  
 (a) Analyses by ICP-MS on HCl digestions  
 (b) Analyses by Hyd Gen / ICP-MS on KOH fusions  
 (c) Analyses by INAA

Element	93C (mg/kg)	93D (mg/kg)	94A (mg/kg)	94B (mg/kg)	94C (mg/kg)	MDL (mg/kg)
Aluminum	125000	115000	101000	102000	101000	80
Antimony (a)	5 7	3 2	1 4	1.4	1 5	0 3
Arsenic	ND	50	ND	ND	ND	40
Barium	272	260	228	191	205	3
Beryllium	4.5	4 4	4 9	5 7	4.7	0 2
Boron	54	72	198	175	215	7
Bromine (c)	10.7	NS	NS	6 60	NS	0 5
Cadmium	ND	ND	ND	ND	ND	10
Calcium	1000	600	1400	1100	1800	500
Cobalt	10	7	19	22	26	4
Copper	31	26	20	44	21	3
Iron	40600	36000	24200	23600	25600	30
Lanthanum	50	44	52	40	39	5
Lead (a)	939	442	232	253	207	2
Lithium	66	62	52	52	55	2
Magnesium	1580	1390	1290	1110	1360	50
Manganese	224	151	1270	1950	1260	4
Phosphorus	920	620	710	770	710	20
Scandium	13 8	11.6	9 0	8 1	8 9	0 3
Selenium	ND	ND	ND	ND	ND	70
Silicon	211000	244000	282000	271000	274000	300
Silver (a)	0.18	0.19	0.13	0 19	0 13	0 02
Sodium	500	500	700	500	1700	200
Strontium	63.8	59 2	46 4	37 1	45 6	0 4
Sulfur	500	400	500	500	400	300
Tin (b)	17	12	8	9	9	1
Titanium	6990	6500	2780	2350	2840	20
Vanadium	109	106	59	49	55	5
Yttrium	22 5	22 2	19 9	15 3	19 1	0.5
Zinc	84	66	84	94	77	5



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4.1. Results of Bulk Elemental Analysis of Soil Litter in the Wooded Areas (continued)

Analyses by ICP-OES on KOH fusions except as noted  
 (a) Analyses by ICP-MS on HCl digestions  
 (b) Analyses by Hyd Gen / ICP-MS on KOH fusions  
 (c) Analyses by INAA

Element	94D (mg/kg)	95A (mg/kg)	95B (mg/kg)	95C (mg/kg)	95D (mg/kg)	MDL (mg/kg)
Aluminum	103000	131000	136000	130000	128000	80
Antimony (a)	1 5	1 8	3 4	2 5	2 8	0 3
Arsenic	ND	ND	ND	ND	ND	40
Barium	208	260	258	232	310	3
Beryllium	5 2	5 5	5.7	5 5	5 5	0 2
Boron	221	100	136	148	130	7
Bromine (c)	6 65	10 5	16 0	NS	NS	0 5
Cadmium	ND	ND	ND	ND	ND	10
Calcium	1300	2800	1100	900	2300	500
Cobalt	21	17	26	28	28	4
Copper	19	27	31	28	31	3
Iron	21400	31400	62100	37000	37600	30
Lanthanum	48	51	52	49	49	5
Lead (a)	225	320	433	331	429	2
Lithium	57	55	61	61	60	2
Magnesium	1200	1450	1860	1940	1920	50
Manganese	643	1580	1500	1860	2560	4
Phosphorus	750	770	820	820	870	20
Scandium	8 6	10 3	12 5	12.0	11.9	0 3
Selenium	ND	ND	ND	ND	ND	70
Silicon	261000	218000	213000	242000	212000	300
Silver (a)	0.13	0 18	0 31	0.19	0 21	0 02
Sodium	400	300	700	600	1300	200
Strontium	33.9	45.4	51 5	47 1	59 0	0 4
Sulfur	500	500	500	500	400	300
Tin (b)	10	17	13	11	10	1
Titanium	2450	3470	4110	3790	3820	20
Vanadium	48	61	82	78	77	5
Yttrium	22 2	15 8	21 2	19 5	20.1	0 5
Zinc	81	700	246	158	1120	5

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5 ROADSIDE SOIL

5.1 Results of Bulk Elemental Analysis of Soil Litter in the Roadside Soil

Analyses by ICP-OES on KOH fusions except as noted  
 (a) Analyses by ICP-MS on HCl digestions  
 (b) Analyses by Hyd Gen / ICP-MS on KOH fusions  
 (c) Analyses by INAA

Element	44A (mg/kg)	44B (mg/kg)	44C (mg/kg)	44D (mg/kg)	45A (mg/kg)	MDL (mg/kg)
Aluminum	76300	68800	68100	76300	75300	50
Antimony (a)	0.58	0.51	0.49	0.85	0.31	0.06
Arsenic	ND	ND	ND	ND	ND	40
Barium	243	372	312	229	263	4
Beryllium	2	1	2	1	2	1
Boron	80	50	90	70	70	10
Bromine (c)	19.8	NS	NS	12.4	NS	0.5
Cadmium	ND	ND	ND	ND	ND	3
Calcium	3400	6400	4200	2000	4500	700
Cobalt	ND	10	10	ND	30	10
Copper	NR	25	NR	44	NR	5
Iron	29100	25100	27600	72200	29100	400
Lanthanum	63	55	71	60	56	7
Lead (a)	102	105	125	61	99	3
Lithium	29	30	29	28	29	5
Magnesium	1400	2000	1600	1000	1600	100
Manganese	218	261	247	488	261	3
Phosphorus	570	670	830	660	800	20
Scandium	8.4	7.4	8.3	8.4	8.5	0.5
Selenium	ND	ND	ND	ND	ND	100
Silicon	241000	255000	276000	241000	198000	300
Sodium	2800	8500	4000	1400	3400	600
Strontium	76	129	93	65	76	2
Sulfur	800	900	800	800	1000	300
Tin (b)	6	5	7	11	6	2
Titanium	4010	3340	4120	3960	3350	4
Vanadium	60	62	73	69	64	5
Yttrium	22	20	26	20	22	2
Zinc	190	110	NR	90	NR	80

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5.1. Results of Bulk Elemental Analysis of Soil Litter in the Roadside Soil (continued)

Analyses by ICP-OES on KOH fusions except as noted  
 (a) Analyses by ICP-MS on HCl digestions  
 (b) Analyses by Hyd Gen / ICP-MS on KOH fusions  
 (c) Analyses by INAA

Element	45B (mg/kg)	45C (mg/kg)	45D (mg/kg)	46A (mg/kg)	46B (mg/kg)	MDL (mg/kg)
Aluminum	56100	74400	96400	61100	59800	50
Antimony	10 8	0 39	0 33	0 41	0 74	0 06
Arsenic	ND	ND	ND	ND	ND	40
Barium	303	219	212	276	309	4
Beryllium	1	3	2	2	3	1
Boron	60	50	120	100	90	10
Bromine	NS	26 2	10 0	17.4	NS	0 5
Cadmium	ND	ND	ND	ND	ND	3
Calcium	5200	3400	1400	4800	7700	700
Cobalt	20	10	20	ND	20	10
Copper	24	NR	23	NR	NR	5
Iron	21700	28300	36700	24700	27400	400
Lanthanum	47	56	89	43	50	7
Lead	201	110	51	437	394	3
Lithium	22	28	36	24	23	5
Magnesium	1700	1400	1200	1600	1900	100
Manganese	258	218	135	262	300	3
Phosphorus	680	680	560	670	570	20
Scandium	6 7	7 8	10 3	6 8	6 9	0 5
Selenium	ND	ND	ND	ND	ND	100
Silicon	251000	223000	247000	293000	239000	300
Sodium	5600	2400	1100	4600	8100	600
Strontium	111	63	59	77	87	2
Sulfur	1000	1000	500	500	500	500
Tin	5	7	9	6	4	2
Titanium	2800	3380	4250	3490	2780	4
Vanadium	49	60	80	50	54	5
Yttrium	20	19	30	24	24	2
Zinc	130	190	ND	NR	NR	80

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5.1. Results of Bulk Elemental Analysis of Soil Litter in the Roadside Soil (continued)

Analyses by ICP-OES on KOH fusions except as noted  
 (a) Analyses by ICP-MS on HCl digestions  
 (b) Analyses by Hyd Gen / ICP-MS on KOH fusions  
 (c) Analyses by INAA

Element	46C (mg/kg)	46D (mg/kg)	47A (mg/kg)	47B (mg/kg)	47C (mg/kg)	MDL (mg/kg)
Aluminum	53100	65000	62100	63300	60800	50
Antimony	0 45	0 34	0 45	0 50	0 70	0 06
Arsenic	ND	ND	ND	ND	ND	40
Barium	257	234	270	288	280	4
Beryllium	2	2	1	2	2	1
Boron	80	80	70	80	80	10
Bromine	NS	16.4	19 6	16 4	NS	0.5
Cadmium	ND	ND	ND	ND	ND	3
Calcium	5900	2500	8500	4500	3600	700
Cobalt	10	ND	10	10	20	10
Copper	NR	NR	27	30	NR	5
Iron	20900	26500	23700	27900	24700	400
Lanthanum	48	57	47	57	54	7
Lead	488	104	211	302	236	3
Lithium	22	24	21	25	26	5
Magnesium	1600	1200	1900	1400	1200	100
Manganese	231	157	302	284	223	3
Phosphorus	610	580	590	660	720	20
Scandium	6 0	7 2	7 1	8 0	7 6	0 5
Selenium	ND	ND	ND	ND	ND	100
Silicon	261000	263000	289000	285000	277000	300
Sodium	4200	1200	9300	4500	2700	600
Strontium	71	62	80	77	72	2
Sulfur	1000	700	900	800	900	300
Tin	5	6	8	6	6	2
Titanium	2860	3590	2760	3760	3450	4
Vanadium	43	57	49	71	61	5
Yttrium	23	21	22	24	23	2
Zinc	240	140	180	NR	NR	80

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5.1. Results of Bulk Elemental Analysis of Soil Litter in the Roadside Soil (continued)

Analyses by ICP-OES on KOH fusions except as noted  
 (a) Analyses by ICP-MS on HCl digestions  
 (b) Analyses by Hyd Gen / ICP-MS on KOH fusions  
 (c) Analyses by INAA

Element	47D (mg/kg)	48A (mg/kg)	48B (mg/kg)	48C (mg/kg)	49A (mg/kg)	MDL (mg/kg)
Aluminum	89600	66000	71900	62500	50500	50
Antimony (a)	0	51	0	41	0	06
Arsenic	ND	ND	ND	ND	ND	40
Barium	249	285	261	232	272	4
Beryllium	2	2	2	1	2	1
Boron	80	80	90	60	80	10
Bromine (c)	NS	NS	16	28.6	28	05
Cadmium	ND	ND	ND	ND	ND	3
Calcium	1600	3200	5200	3300	4600	700
Cobalt	20	10	10	ND	ND	10
Copper	NR	17	23	NR	NR	5
Iron	36600	25000	30200	23600	21000	400
Lanthanum	62	64	69	60	30	7
Lead (a)	74	256	315	234	568	3
Lithium	36	26	25	23	18	5
Magnesium	1000	1200	1500	1300	1400	100
Manganese	112	214	256	192	231	3
Phosphorus	490	710	590	530	790	20
Scandium	9.5	7	9	6	5.6	0.5
Selenium	ND	ND	ND	ND	ND	100
Silicon	280000	289000	279000	266000	274000	300
Sodium	1000	3300	4600	1800	3900	600
Strontium	65	75	71	62	68	2
Sulfur	400	700	800	800	1100	300
Tin (b)	8	7	5	5	8	2
Titanium	4620	3610	3480	3460	2840	4
Vanadium	83	60	66	42	48	5
Yttrium	25	30	32	25	16	2
Zinc	ND	NR	170	200	350	80

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5.1. Results of Bulk Elemental Analysis of Soil Litter in the Roadside Soil (continued)

Analyses by ICP-OES on KOH fusions except as noted  
 (a) Analyses by ICP-MS on HCl digestions  
 (b) Analyses by Hyd Gen / ICP-MS on KOH fusions  
 (c) Analyses by INAA

Element	49B (mg/kg)	49C (mg/kg)	49D (mg/kg)	50A (mg/kg)	50B (mg/kg)	MDL (mg/kg)
Aluminum	50600	52500	55000	57800	51500	50
Antimony	0.74	0.72	0.61	0.71	0.67	0.06
Arsenic	ND	ND	ND	ND	ND	40
Barium	278	274	247	337	352	4
Beryllium	3	2	2	2	2	1
Boron	90	80	100	80	40	10
Bromine	NS	27.1	NS	NS	NS	0.5
Cadmium	ND	ND	ND	ND	ND	3
Calcium	5200	4300	4000	8200	7900	700
Cobalt	10	ND	10	20	10	10
Copper	20	NR	20	21	NR	5
Iron	20400	24500	23100	24200	20600	400
Lanthanum	39	37	47	56	49	7
Lead	405	491	232	180	155	3
Lithium	20	25	25	20	20	5
Magnesium	1500	1400	1400	1900	2000	100
Manganese	260	264	191	281	307	3
Phosphorus	640	840	710	580	620	20
Scandium	5.8	6.5	7.1	6.8	5.6	0.5
Selenium	ND	ND	ND	ND	ND	100
Silicon	303000	282000	325000	314000	290000	300
Sodium	6100	3800	3000	10800	9000	600
Strontium	81	72	65	118	137	2
Sulfur	800	1100	600	700	900	300
Tin	5	6	6	5	5	2
Titanium	2710	3090	3370	2860	2450	4
Vanadium	48	61	60	55	45	5
Yttrium	20	16	30	30	22	2
Zinc	210	NR	NR	80	NR	80

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5.1. Results of Bulk Elemental Analysis of Soil Litter in the Roadside Soil (continued)

Analyses by ICP-OES on KOH fusions except as noted  
 (a) Analyses by ICP-MS on HCl digestions  
 (b) Analyses by Hyd Gen / ICP-MS on KOH fusions  
 (c) Analyses by INAA

Element	50C (mg/kg)	50D (mg/kg)	51A (mg/kg)	51B (mg/kg)	51C (mg/kg)	MDL (mg/kg)
Aluminum	58400	56800	59300	61300	55200	50
Antimony	0.73	0.71	0.75	0.46	0.54	0.06
Arsenic	ND	ND	ND	ND	ND	40
Barium	347	314	213	239	237	4
Beryllium	2	2	2	2	2	1
Boron	50	60	60	50	60	10
Bromine	5.6	11.8	5.2	7.3	5.2	0.5
Cadmium	ND	ND	ND	ND	ND	3
Calcium	8000	6900	3200	5100	7600	700
Cobalt	10	10	10	ND	10	10
Copper	18	20	21	NR	NR	5
Iron	24400	23400	22000	23200	23400	400
Lanthanum	43	45	65	55	64	7
Lead	195	337	82	140	79	3
Lithium	21	27	21	23	19	5
Magnesium	1900	2200	1200	1500	1500	100
Manganese	256	250	204	217	207	3
Phosphorus	530	710	550	480	490	20
Scandium	6.9	6.9	6.7	6.9	6.5	0.5
Selenium	ND	ND	ND	ND	ND	100
Silicon	323000	293000	313000	276000	294000	300
Sodium	9700	7700	3100	3800	3300	600
Strontium	114	105	64	71	63	2
Sulfur	900	800	500	500	400	300
Tin	4	8	5	4	4	2
Titanium	2750	3060	3570	3470	3300	4
Vanadium	58	58	58	51	56	5
Yttrium	21	25	29	29	29	2
Zinc	NR	NR	NR	NR	NR	80

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5.1. Results of Bulk Elemental Analysis of Soil Litter in the Roadside Soil (continued)

Analyses by ICP-OES on KOH fusions except as noted  
 (a) Analyses by ICP-MS on HCl digestions  
 (b) Analyses by Hyd Gen / ICP-MS on KOH fusions  
 (c) Analyses by INAA

Element	51D (mg/kg)	52A (mg/kg)	52B (mg/kg)	52C (mg/kg)	52D (mg/kg)	MDL (mg/kg)
Aluminum	57100	58400	80200	57100	68100	50
Antimony	0.52	0.57	0.80	0.49	1.26	0.06
Arsenic	ND	ND	ND	ND	ND	40
Barium	201	227	287	246	267	4
Beryllium	2	1	2	2	2	1
Boron	60	40	30	30	50	10
Bromine	NS	NS	3.3	NS	4.9	0.5
Cadmium	ND	ND	ND	ND	ND	3
Calcium	3800	6400	7300	6900	7000	700
Cobalt	20	20	10	20	10	10
Copper	NR	19	NR	NR	NR	5
Iron	21600	22100	27800	22900	26400	400
Lanthanum	68	26	40	29	32	7
Lead	63	81	70	101	111	3
Lithium	20	18	22	20	23	5
Magnesium	1000	1400	1900	1600	1700	100
Manganese	147	246	261	260	290	3
Phosphorus	490	620	670	630	540	20
Scandium	6.3	7.1	8.7	6.8	7.6	0.5
Selenium	ND	ND	ND	ND	ND	100
Silicon	323000	255000	263000	229000	267000	300
Sodium	3600	5000	8100	5600	6200	600
Strontium	50	77	109	88	101	2
Sulfur	400	900	600	800	600	300
Tin	4	6	5	NA	5	2
Titanium	3440	2310	3070	2280	2680	4
Vanadium	56	51	62	51	55	5
Yttrium	36	10	18	11	28	2
Zinc	NR	NR	NR	NR	NR	80



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5.1. Results of Bulk Elemental Analysis of Soil Litter in the Roadside Soil (continued)

Analyses by ICP-OES on KOH fusions except as noted  
(a) Analyses by ICP-MS on HCl digestions  
(b) Analyses by Hyd Gen / ICP-MS on KOH fusions  
(c) Analyses by INAA

Element	53A (mg/kg)	53B (mg/kg)	53C (mg/kg)	53D (mg/kg)	54C (mg/kg)	MDL (mg/kg)
Aluminum	93400	93600	81000	53300	78500	50
Antimony	0 37	0 47	0 39	0 53	0 37	0 06
Arsenic	ND	ND	ND	ND	ND	40
Barium	181	204	221	308	195	4
Beryllium	2	2	2	2	2	1
Boron	40	60	50	70	80	10
Bromine	NS	NS	15 6	13 7	10 2	0 5
Cadmium	ND	ND	ND	ND	ND	3
Calcium	2800	1900	2900	4800	1700	700
Cobalt	20	ND	10	20	10	10
Copper	20	NR	23	28	NR	5
Iron	41700	42500	33400	20200	29400	400
Lanthanum	60	55	69	55	48	7
Lead	45	61	123	275	55	3
Lithium	27	25	23	20	24	5
Magnesium	1100	900	1200	1400	900	100
Manganese	194	146	189	243	132	3
Phosphorus	600	480	640	550	450	20
Scandium	12.1	11 9	9 8	6.6	8.8	0 5
Selenium	ND	ND	ND	ND	ND	100
Silicon	216000	251000	255000	290000	294000	300
Sodium	700	800	1900	4600	1700	600
Strontium	44	41	55	87	49	2
Sulfur	500	400	600	600	500	300
Tin	6	6	7	5	6	2
Titanium	4510	4810	4420	3160	3310	4
Vanadium	90	93	69	51	72	5
Yttrium	25	25	26	22	17	2
Zinc	90	ND	100	NR	NR	80

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5.1. Results of Bulk Elemental Analysis of Soil Litter in the Roadside Soil (continued)

Analyses by ICP-OES on KOH fusions except as noted  
 (a) Analyses by ICP-MS on HCl digestions  
 (b) Analyses by Hyd Gen / ICP-MS on KOH fusions  
 (c) Analyses by INAA

Element	54D (mg/kg)	55A (mg/kg)	55B (mg/kg)	55D (mg/kg)	56A (mg/kg)	MDL (mg/kg)
Aluminum	75800	62900	66600	62800	64700	50
Antimony	0	0	0	0	0	0
Arsenic	ND	ND	ND	ND	ND	0
Barium	269	260	241	285	253	40
Beryllium	2	2	3	2	1	4
Boron	50	100	90	60	20	1
Bromine	NS	NS	9.2	NS	7	10
Cadmium	ND	ND	ND	ND	ND	0
Calcium	4600	3100	2500	5900	4600	3
Cobalt	30	30	20	40	ND	700
Copper	NR	NR	NR	30	NR	10
Iron	27400	23700	27100	29700	29400	5
Lanthanum	51	51	61	56	49	400
Lead	167	79	89	110	135	7
Lithium	26	22	23	22	17	3
Magnesium	1500	1200	1000	1500	1500	5
Manganese	192	181	173	248	267	100
Phosphorus	530	590	570	710	320	3
Scandium	8.6	7	8	8	8	20
Selenium	ND	ND	ND	ND	ND	0
Silicon	259000	302000	301000	281000	304000	5
Sodium	5300	2500	1700	5100	4200	100
Strontium	85	72	64	88	61	300
Sulfur	600	600	500	800	400	600
Tin	5	6	6	6	4	2
Titanium	3090	3620	3750	3170	3050	4
Vanadium	66	62	71	63	53	5
Yttrium	19	21	29	22	37	2
Zinc	NR	NR	NR	NR	NR	80

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5.1. Results of Bulk Elemental Analysis of Soil Litter in the Roadside Soil (continued)

Analyses by ICP-OES on KOH fusions except as noted  
(a) Analyses by ICP-MS on HCl digestions  
(b) Analyses by Hyd Gen / ICP-MS on KOH fusions  
(c) Analyses by INAA

Element	56B (mg/kg)	56C (mg/kg)	56D (mg/kg)	57A (mg/kg)	57B (mg/kg)	MDL (mg/kg)
Aluminum	77600	55500	54800	64000	64300	50
Antimony	0.41	0.51	0.42	0.42	0.52	0.06
Arsenic	ND	ND	ND	ND	ND	40
Barium	269	358	360	288	178	4
Beryllium	1	1	2	2	2	1
Boron	40	10	30	50	60	10
Bromine	NS	4.2	4.8	NS	NS	0.5
Cadmium	ND	ND	ND	ND	ND	3
Calcium	3500	10300	10300	6600	4900	700
Cobalt	30	ND	10	20	10	10
Copper	31	NR	NR	30	NR	5
Iron	32400	24200	18500	23000	22100	400
Lanthanum	39	27	33	37	37	7
Lead	109	148	129	97	71	3
Lithium	21	14	17	24	24	5
Magnesium	1400	2000	2400	1900	1400	100
Manganese	289	288	270	294	171	3
Phosphorus	500	300	380	690	360	20
Scandium	11.1	7.8	6.1	7.8	6.1	0.5
Selenium	ND	ND	ND	ND	ND	100
Silicon	282000	329000	322000	271000	272000	300
Sodium	3500	8100	12800	8800	3500	600
Strontium	58	84	112	99	63	2
Sulfur	400	500	400	900	600	300
Tin	5	3	4	6	5	2
Titanium	3350	2340	1960	2630	2520	4
Vanadium	73	49	34	50	35	5
Yttrium	19	17	17	19	17	2
Zinc	NR	ND	NR	NR	ND	80

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5.1. Results of Bulk Elemental Analysis of Soil Litter in the Roadside Soil (continued)

Analyses by ICP-OES on KOH fusions except as noted  
 (a) Analyses by ICP-MS on HCl digestions  
 (b) Analyses by Hyd Gen / ICP-MS on KOH fusions  
 (c) Analyses by INAA

Element	57C (mg/kg)	57D (mg/kg)	58A (mg/kg)	58C (mg/kg)	58D (mg/kg)	MDL (mg/kg)
Aluminum	67300	51500	75100	77400	61100	50
Antimony	0 54	0 82	0 34	1 39	0 60	0 06
Arsenic	ND	ND	ND	ND	ND	40
Barium	301	377	269	256	392	4
Beryllium	2	2	1	ND	2	1
Boron	50	40	ND	10	40	10
Bromine	10 0	8 2	3 7	NS	3 2	0 5
Cadmium	ND	ND	ND	ND	ND	3
Calcium	6600	10200	9800	9600	7500	700
Cobalt	10	10	10	20	10	10
Copper	NR	NR	NR	27	NR	5
Iron	25300	17600	27900	29900	32800	400
Lanthanum	49	37	17	20	48	7
Lead	98	135	30	25	74	3
Lithium	23	18	17	17	23	5
Magnesium	1700	2000	2000	1900	2200	100
Manganese	229	244	257	278	223	3
Phosphorus	500	490	320	310	450	20
Scandium	8 1	5 1	10 3	11 8	9 8	0 5
Selenium	ND	ND	ND	ND	ND	100
Silicon	277000	317000	296000	284000	311000	300
Sodium	6900	13000	11600	10100	10000	600
Strontium	104	150	63	61	130	2
Sulfur	600	800	800	400	600	300
Tin	5	4	3	3	4	2
Titanium	2850	1900	2340	2390	3050	4
Vanadium	48	35	59	69	90	5
Yttrium	26	15	15	14	16	2
Zinc	NR	NR	NR	NR	NR	80

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5.1. Results of Bulk Elemental Analysis of Soil Litter in the Roadside Soil (continued)

Analyses by ICP-OES on KOH fusions except as noted  
 (a) Analyses by ICP-MS on HCl digestions  
 (b) Analyses by Hyd Gen / ICP-MS on KOH fusions  
 (c) Analyses by INAA

Element	59A (mg/kg)	59B (mg/kg)	59C (mg/kg)	59D (mg/kg)	60A (mg/kg)	MDL (mg/kg)
Aluminum	60200	83100	49600	56800	74700	50
Antimony	0 57	0.60	6.41	0 90	0 39	0 06
Arsenic	ND	ND	ND	ND	ND	40
Barium	341	283	358	383	246	4
Beryllium	1	2	2	2	2	1
Boron	70	70	80	70	100	10
Bromine	NS	11 2	NS	8 7	NS	0 5
Cadmium	ND	ND	ND	ND	ND	3
Calcium	3400	2600	5300	5100	3000	700
Cobalt	10	10	10	ND	10	10
Copper	20	NR	21	NR	23	5
Iron	22700	32100	19500	25700	25000	400
Lanthanum	53	64	57	59	52	7
Lead	202	92	444	164	111	3
Lithium	27	32	27	24	29	5
Magnesium	1400	1400	1400	1600	1300	100
Manganese	210	207	232	231	175	3
Phosphorus	550	580	530	510	600	20
Scandium	6.9	9 5	6.4	7.9	7 8	0 5
Selenium	ND	ND	ND	ND	ND	100
Silicon	300000	285000	305000	308000	253000	300
Sodium	3400	1600	3600	7000	1900	600
Strontium	90	66	99	106	59	2
Sulfur	600	500	700	600	600	300
Tin	6	7	6	8	12	2
Titanium	3410	3820	3320	3050	2670	4
Vanadium	57	70	56	60	55	5
Yttrium	23	21	23	24	15	2
Zinc	100	130	NR	NR	NR	80

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5.1. Results of Bulk Elemental Analysis of Soil Litter in the Roadside Soil (continued)

Analyses by ICP-OES on KOH fusions except as noted  
 (a) Analyses by ICP-MS on HCl digestions  
 (b) Analyses by Hyd Gen / ICP-MS on KOH fusions  
 (c) Analyses by INAA

Element	60B (mg/kg)	60C (mg/kg)	60D (mg/kg)	MDL (mg/kg)
Aluminum	82400	82900	75400	50
Antimony	0.43	0.40	0.45	0.06
Arsenic	ND	ND	ND	40
Barium	241	237	265	4
Beryllium	1	2	2	1
Boron	90	490	590	10
Bromine	6.3	9.5	NS	0.5
Cadmium	ND	ND	ND	3
Calcium	1500	2200	4600	700
Cobalt	20	20	10	10
Copper	15	18	NR	5
Iron	18800	21900	24500	400
Lanthanum	51	54	43	7
Lead	48	78	102	3
Lithium	32	32	29	5
Magnesium	1000	1500	1700	100
Manganese	148	161	313	3
Phosphorus	500	530	480	20
Scandium	7.4	8.0	8.5	0.5
Selenium	ND	ND	ND	100
Silicon	251000	276000	285000	300
Sodium	700	1700	6200	600
Strontium	48	53	74	2
Sulfur	400	500	300	300
Tin	8	6	6	2
Titanium	1620	2320	2840	4
Vanadium	43	50	52	5
Yttrium	12	14	18	2
Zinc	NR	NR	NR	80

**APPENDIX B**

**Results of Analysis of Lead Isotope Ratios in Bulk Samples**

APPENDIX B

Results of Analysis of Lead Isotope Ratios in Bulk Samples

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## 1. INTRODUCTION

Data results for lead isotope ratio analysis of the following are presented in this appendix: soil litter in the Westgate Trailer Park, attic dust in the Westgate Trailer Park, soil litter at the Exide facility, process material and dust at the Exide facility, soil litter in the wooded areas, and soil litter in the roadside soil. Samples underwent hydrochloric acid dissolution prior to analysis, as described in the Methods section of the report.

## 2. WESTGATE TRAILER PARK

### 2.1. Lead Isotope Ratios in Soil Litter

Sample	$^{204}\text{Pb}/^{206}\text{Pb}$	$^{207}\text{Pb}/^{206}\text{Pb}$	$^{208}\text{Pb}/^{206}\text{Pb}$	Sample	$^{204}\text{Pb}/^{206}\text{Pb}$	$^{207}\text{Pb}/^{206}\text{Pb}$	$^{208}\text{Pb}/^{206}\text{Pb}$
01A	0 0521	0 8153	2 0057	11A	0 0531	0 8351	2 0514
01B	0 0519	0 8165	2 0197	11B	0 0522	0 8254	2 0353
01C	0 0521	0 8172	2 0214	11C	0 0523	0 8253	2 0294
01D	0 0520	0 8183	2 0212	11D	0 0536	0 8440	2 0637
02A	0 0520	0 8153	2 0126	12A	0 0520	0 8210	2 0253
02B	0 0520	0 8171	2 0157	12B	0 0521	0 8215	2 0102
02C	0 0518	0 8127	2 0085	12C	0 0520	0 8230	2 0272
02D	0 0521	0 8193	2 0177	12D	0 0518	0 8184	2 0162
03A	0 0523	0 8221	2 0257	13A	0 0525	0 8273	2 0298
03B	0 0520	0 8183	2 0228	13B	0 0525	0 8264	2 0295
03C	0 0519	0 8177	2 0200	13C	0 0520	0 8236	2 0333
03D	0 0522	0 8212	2 0235	13D	0 0525	0 8285	2 0364
04A	0 0520	0 8170	2 0147	14A	0 0516	0 8169	2 0137
04B	0 0519	0 8168	2 0164	14B	0 0518	0 8163	2 0102
04C	0 0523	0 8219	2 0219	14C	0 0515	0 8172	2 0189
04D	0 0519	0 8173	2 0157	14D	0 0515	0 8150	2 0128
05A	0 0518	0 8193	2 0282	15A	0 0516	0 8156	2 0091
05B	0.0516	0 8171	2 0235	15B	0 0517	0 8168	2 0146
05C	0.0519	0.8193	2 0282	15C	0 0515	0 8150	2 0132
05D	0 0516	0 8155	2 0206	15D	0 0513	0 8116	2 0010
06A	0 0523	0 8259	2 0384	16A	0 0519	0 8199	2 0197
06B	0 0519	0 8230	2 0421	16B	0 0516	0 8169	2 0198
06C	0 0524	0 8271	2 0355	16C	0 0515	0 8134	2 0146
06D	0 0518	0 8181	2 0181	16D	0 0513	0.8120	2 0038
07A	0 0520	0 8176	2 0159	17A	0 0521	0 8186	2 0109
07B	0 0517	0 8188	2 0284	17B	0 0519	0 8159	2 0071
07C	0 0518	0 8186	2 0252	17C	0 0522	0 8197	2 0128
07D	0.0522	0 8206	2 0223	17D	0 0522	0 8213	2 0183
08A	0 0514	0 8135	2 0138	18A	0 0516	0 8139	2 0050
08B	0 0515	0 8153	2 0181	18B	0 0516	0 8127	2 0037
08C	0 0517	0 8148	2 0143	18C	0 0516	0 8147	2 0094
08D	0 0518	0 8149	2 0116	18D	0 0521	0 8201	2 0143
09A	0 0515	0 8136	2 0122	19A	0.0523	0 8224	2 0237
09B	0 0515	0 8139	2 0158	19B	0 0519	0 8178	2 0131
09C	0 0513	0 8134	2 0162	19C	0 0520	0 8192	2 0144
09D	0 0514	0 8134	2 0166	19D	0 0522	0 8202	2 0186
10A	0 0520	0 8213	2 0281	20A	0 0521	0 8222	2 0184
10B	0 0518	0 8198	2 0278	20B	0 0522	0 8214	2 0122
10C	0 0515	0.8153	2 0207	20C	0 0524	0 8239	2 0259
10D	0 0523	0 8236	2 0293	20D	0 0523	0 8261	2 0265

### 2.2. Lead Isotope Ratios in Attic Dust

Sample	$^{204}\text{Pb}/^{206}\text{Pb}$	$^{207}\text{Pb}/^{206}\text{Pb}$	$^{208}\text{Pb}/^{206}\text{Pb}$
96	0 0530	0 8307	2 0378
97	0 0529	0 8274	2 0320
98	0 0527	0.8256	2 0265

### 3. EXIDE BATTERY FACILITY

#### 3.1. Lead Isotope Ratios in Process Material and Dust

Sample	$^{204}\text{Pb}/^{206}\text{Pb}$	$^{207}\text{Pb}/^{206}\text{Pb}$	$^{208}\text{Pb}/^{206}\text{Pb}$
21	0 0511	0 8105	2 0032
22	0 0513	0 8150	2 0155
23	0 0511	0 8078	1 9958
24	0 0515	0 8171	2 0222
25	0 0513	0 8121	2 0033
26	0 0508	0 8077	2 0002
27	0 0515	0 8130	1 9984
28	0 0513	0 8133	2 0174
29	0 0515	0 8114	2 0003
30	0 0513	0 8146	2 0134
31	0 0510	0 8099	2 0117
32	0 0511	0 8122	2 0103
36	0 0513	0 8140	2 0164
37	0 0514	0 8118	2 0044
38	0 0517	0 8197	2 0226
39	0 0516	0 8102	1 9956
40	0 0531	0 8390	2 0557
90	0 0513	0 8142	2 0146

#### 3.2. Lead Isotope Ratios in Soil Litter

Sample	$^{204}\text{Pb}/^{206}\text{Pb}$	$^{207}\text{Pb}/^{206}\text{Pb}$	$^{208}\text{Pb}/^{206}\text{Pb}$
33A	0 0512	0 8097	2 0029
33B	0 0517	0 8133	2 0013
33C	0 0511	0 8095	2 0080
33D	0 0515	0 8115	2 0018
34A	0 0521	0 8191	2 0177
34B	0 0518	0 8159	2 0145
34C	0 0519	0 8188	2 0228
34D	0 0519	0 8186	2 0197
35A	0 0520	0 8161	1 9994
35B	0 0515	0 8128	2 0083
35C	0 0516	0 8136	2 0090
35D	0 0519	0 8164	2 0131

# 4. WOODED AREAS

## 4.1. Lead Isotope Ratios in Soil Litter

Sample	<sup>204</sup> Pb/ <sup>206</sup> Pb	<sup>207</sup> Pb/ <sup>206</sup> Pb	<sup>208</sup> Pb/ <sup>206</sup> Pb	Sample	<sup>204</sup> Pb/ <sup>206</sup> Pb	<sup>207</sup> Pb/ <sup>206</sup> Pb	<sup>208</sup> Pb/ <sup>206</sup> Pb
61A	0 0516	0 8113	2 0014	74A	0 0513	0 8136	2 0203
61A	0 0516	0 8143	2 0105	74B	0 0509	0 8074	2 0084
61C	0 0512	0 8103	2 0021	74C	0 0513	0 8134	2 0198
61D	0 0515	0 8128	2 0094	74D	0 0514	0 8135	2 0215
62A	0 0524	0 8236	2 0262	75A	0 0515	0 8149	2 0234
62B	0 0523	0 8215	2 0218	75B	0 0523	0 8251	2 0437
62C	0 0523	0 8223	2 0216	75C	0 0516	0 8159	2 0205
62D	0 0523	0 8221	2 0222	75D	0 0525	0 8298	2 0478
63A	0 0524	0 8243	2 0272	76A	0 0516	0 8168	2 0241
63B	0 0524	0 8242	2 0257	76B	0 0513	0 8083	1 9993
63C	0 0519	0 8179	2 0184	76C	0 0518	0 8173	2 0156
63D	0 0518	0 8170	2 0176	76D	0 0521	0 8179	2 0160
64A	0 0513	0 8100	1 9999	77A	0 0524	0 8236	2 0290
64B	0 0510	0 8062	1 9966	77B	0 0526	0 8289	2 0381
64C	0 0515	0 8095	2 0018	77C	0 0524	0 8255	2 0313
64D	0 0521	0 8194	2 0183	77D	0 0525	0 8245	2 0296
65A	0 0515	0 8122	2 0087	78A	0 0531	0 8321	2 0441
65B	0 0514	0 8114	2 0067	78B	0 0529	0 8317	2 0428
65C	0 0517	0 8140	2 0066	78C	0 0532	0 8336	2 0462
65D	0 0513	0 8089	2 0001	78D	0 0532	0 8330	2 0406
66A	0 0511	0 8074	1 9951	91A	0 0521	0 8180	2 0171
66B	0 0510	0 8055	1 9958	91B	0 0519	0 8168	2 0145
66C	0 0513	0 8080	1 9961	91C	0 0518	0 8170	2 0149
66D	0 0511	0 8054	1 9930	91D	0 0530	0 8312	2 0403
67A	0 0519	0 8189	2 0162	92A	0 0528	0 8298	2 0405
67B	0 0519	0 8189	2 0162	92B	0 0528	0 8263	2 0245
67C	0 0520	0 8219	2 0328	92C	0 0527	0 8274	2 0326
67D	0 0520	0 8221	2 0323	92D	0 0532	0 8326	2 0388
71A	0 0512	0 8118	2 0140	93A	0 0520	0 8172	2 0156
71B	0 0517	0 8202	2 0298	93B	0 0521	0 8194	2 0187
71C	0 0514	0 8158	2 0236	93C	0 0520	0 8188	2 0176
71D	0 0516	0 8175	2 0236	93D	0 0517	0 8150	2 0122
72A	0 0517	0 8192	2 0262	94A	0 0518	0 8109	1 9941
72B	0 0510	0 8079	2 0039	94B	0 0518	0 8133	1 9998
72C	0 0518	0 8187	2 0254	94C	0 0516	0 8112	1 9962
72D	0 0515	0 8153	2 0210	94D	0 0518	0 8138	2 0028
73A	0 0517	0 8174	2 0277	95A	0 0521	0 8177	2 0141
73B	0 0518	0 8189	2 0314	95B	0 0524	0 8199	2 0160
73C	0 0515	0 8156	2 0253	95C	0 0520	0 8167	2 0098
73D	0 0523	0 8231	2 0350	95D	0 0520	0 8167	2 0110

## 5. ROADSIDE SOIL

## 5.1. Lead Isotope Ratios in Soil Litter

Sample	$^{204}\text{Pb}/^{206}\text{Pb}$	$^{207}\text{Pb}/^{206}\text{Pb}$	$^{208}\text{Pb}/^{206}\text{Pb}$	Sample	$^{204}\text{Pb}/^{206}\text{Pb}$	$^{207}\text{Pb}/^{206}\text{Pb}$	$^{208}\text{Pb}/^{206}\text{Pb}$
44A	0 0519	0 8183	2 0223	53A	0 0519	0 8122	2 0253
44B	0 0515	0 8144	2 0156	53B	0 0526	0 8241	2 0407
44C	0 0518	0 8176	2 0210	53C	0 0522	0 8182	2 0256
44D	0 0520	0 8214	2.0280	53D	0 0518	0 8137	2 0085
45A	0 0514	0 8136	2 0150	54C	0 0521	0 8162	2 0216
45B	0 0514	0 8146	2 0110	54D	0 0518	0 8143	2 0124
45C	0 0517	0 8148	2 0198	55A	0 0525	0 8216	2 0259
45D	0 0513	0 8107	2 0319	55B	0 0516	0 8100	2 0061
46A	0 0518	0 8147	2 0034	55D	0 0517	0 8144	2 0089
46B	0 0516	0 8147	2 0070	56A	0 0519	0 8158	2 0175
46C	0 0516	0 8127	2 0018	56B	0 0523	0 8191	2 0240
46D	0 0519	0 8202	2.0285	56C	0 0517	0 8159	2 0200
47A	0 0518	0 8183	2 0157	56D	0 0515	0 8132	2 0119
47B	0 0519	0 8186	2 0096	57A	0 0516	0 8132	2 0144
47C	0 0521	0 8218	2 0240	57B	0 0513	0 8101	2 0032
47D	0 0522	0 8228	2 0378	57C	0 0508	0 8026	1 9934
48A	0 0518	0 8178	2 0186	57D	0 0508	0 8015	1 9853
48B	0 0518	0 8165	2 0145	58A	0 0521	0 8170	2 0240
48C	0 0518	0 8181	2 0187	58C	0 0523	0 8195	2 0330
49A	0 0517	0 8175	2 0161	58D	0 0509	0 8048	1 9967
49B	0 0516	0 8158	2 0091	59A	0 0520	0 8185	2 0182
49C	0 0516	0 8160	2 0127	59B	0 0523	0 8228	2 0312
49D	0 0520	0 8214	2 0266	59C	0 0515	0 8101	2 0012
50A	0 0513	0 8118	2 0077	59D	0 0515	0 8130	2 0087
50B	0 0516	0 8119	2 0047	60A	0 0520	0 8203	2 0225
50C	0 0518	0 8159	2 0143	60B	0 0523	0 8239	2 0371
50D	0 0518	0 8148	2 0093	60C	0 0521	0 8215	2 0243
51A	0 0522	0 8193	2 0263	60D	0 0516	0 8143	2 0149
51B	0 0525	0 8230	2 0258				
51C	0 0523	0 8201	2 0253				
51D	0 0523	0 8179	2 0269				
52A	0 0518	0 8134	2 0105				
52B	0 0518	0 8140	2 0134				
52C	0 0517	0 8112	2 0062				
52D	0 0515	0 8105	2 0027				

**APPENDIX C**

**Summary of the Results of Individual Particle Analysis**

APPENDIX C

Summary of the Results of Individual Particle Analysis

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## 1. INTRODUCTION

Presented in this appendix is a summary of the results of individual particle analysis (IPA) conducted on lead bearing particles. IPA was conducted on lead bearing particles in seven sets of samples including soil litter from soil cores collected in the Westgate Trailer Park, at the Exide facility, in wooded areas adjacent to the Exide facility, and in roadside soil. Sample sets also included attic dust collected in the Westgate Trailer Park and air filters, process material, and dust collected at the Exide facility

IPA was conducted by scanning electron microscopy (SEM) and energy dispersive X-ray spectrometry (EDS). Elemental composition and estimates of major, minor, and trace element abundance were determined from EDS spectra of the lead bearing particles. Estimates of major, minor, and trace element abundance were based on the relative net EDS response. Major element abundances represented an estimated elemental abundance greater than approximately 30% by weight (>30%). Minor element abundance represented an estimated 10 to 30% by weight (10-30%). Finally, trace element abundance represented an estimated elemental abundance less than 10% (<10%).

Lead bearing particles were classified based on the relative abundance of antimony (Sb), barium (Ba), chlorine (Cl), chromium (Cr), copper (Cu), lead (Pb), manganese (Mn), nickel (Ni), phosphorous (P), tin (Sn), sulfur (S), and zinc (Zn), as well as iron (Fe) where present in major abundance. In addition to particle class descriptions including the above elements, particle classes were assigned a particle class identity (ID) number. The frequency of lead bearing particles in each class for each of the seven sample sets examined is summarized in Table 3-8. Particle size data are summarized for each of the seven sample sets in Table 3-9.

The presence and relative abundance of other elements such as aluminum (Al), bromine (Br), calcium (Ca), potassium (K), silicon (Si), and titanium (Ti), as well as the presence of iron (Fe) in minor or trace abundance were also documented. When collected, the EDS spectrum from the area surrounding and including the particle was also considered in the estimate of abundance of these elements. However, these elements were not used for particle class determination due to commonly encountered interference from the presence of these elements in adjacent material. Thus, the presence of these elements was simply noted in parenthesis following the particle class descriptions. In addition, an overlap in the responses for aluminum and bromine in EDS spectra prevented these elements from being distinguished in the particles analyzed. For this reason, the EDS response for aluminum and bromine is indicated by Al/Br.



Determinations of particle dimensions were made from secondary and backscattered electron images of the particles. Two particle size measurements are given in micrometers: the longest particle diameter (Long Diam) measurable in the SEM images and the particle diameter perpendicular (Perp Diam) to the longest diameter.

IPA results from Exide process material and dust were grouped together based on the area at the Exide facility where a sample was collected or the type of sample collected. It should be noted that the IPA data summary tables are divided between two pages where table columns are continued onto the following page.

## 2. WESTGATE TRAILER PARK

### 2.1. Summary of IPA Results of Soil Litter in the Westgate Trailer Park

SEM Sample No	Set No	Particle No	M a j o r P b S b S n	E l e m e n t s A l S i C a M n F e K T l C u Z n C l P b S b S n	M i n o r B a A l S i C a M n F e K T l C u Z n C l P b S b S n	E l e m e n t s B r	Br	Table Columns Continued on next page...
01A	1	1 1	X					
01A	1	2 1	X					
01A	1	3 1	X					
01A	1	4 1	X					
01A	1	5 1	X					
01A	1	6 1	X					
01A	1	7 1	X					
01A	2	1 1	X					
01A	2	2 1	X					
01A	2	3 1	X					
01A	2	4 1	X					
01A	2	5 1	X					
01A	2	6 1	X					
01A	2	7 1	X					
01A	2	7 2	X					
01A	2	7 3	X					
01A	2	7 4	X					
01A	2	7 5	X					
01A	2	7 6	X					
01A	2	8 1	X					
02A	1	1 1	X					
02A	1	2 1	X					
02A	1	3 1	X					
02A	1	4 1	X					
02A	1	5 1	X					
02A	1	6 1	X					
02A	1	7 1	X					
02A	1	8 1	X					
02A	2	1 1	X					
02A	2	2 1	X					
02A	2	3 1	X					
02A	2	4 1	X					
02A	2	5 1	X					
02A	2	6 1	X					
02A	2	7 1	X					
03A	1	1 1	X					
03A	1	2 1	X					
03A	1	3 1	X					
03A	1	4 1	X					
03A	1	5 1	X					

## 2.1. Summary of IPA Results of Soil Litter in the Westgate Trailer Park (continued)

...Table Columns Continued from last page

Sample No	SEM Set No	Particle No	T r a c e Pb Sb Sn P Ba Al/ Si	E l e m e n t s Ca Mn Fe K Ti Cu Zn Cl Cr	Long Perp Diam Shape (µm)	Particle Class	Particle Class	Particle Class
01A	1	1 1	x x x	x	220 0 135.0 blocky	Pb-rich with P Cu	(Al/Br Si Ca)	21
01A	1	2 1	x	x x x	3 5 1.5 irreg	Pb-rich with P Cu	(Al/Br Si Fe Ca K Ti)	21
01A	1	3 1	x	x x	1.5 1 0 irreg	Pb-rich with P Cu	(Al/Br Si Fe)	21
01A	1	4 1	x	x x	1 0 1 0 irreg	Pb-rich with P Cu	(Al/Br Si Fe)	21
01A	1	5 1	x	x x	1 7 1 7 irreg	Pb-rich with P Cu	(Al/Br Si Fe Ca)	21
01A	1	6 1	x	x x	0 8 0 8 irreg	Pb-rich with P Cu	(Al/Br Si Fe Ca K Ti)	21
01A	1	7 1	x	x x	1 7 1 1 irreg	Pb-rich with P Cu	(Al/Br Si Fe Ca K Ti)	21
01A	2	1 1	x x x	x x x	7 6 6 0 irreg	Pb-rich with P Cu	(Al/Br Si Fe Ca)	21
01A	2	2 1	x x x	x x	1 7 1 7 irreg	Pb-rich with P Cu	(Al/Br Si Fe Ca)	21
01A	2	3 1	x x x	x	3 0 2.3 ovoid	Pb-rich with Sb Sn Cu	(Al/Br Si Fe)	10
01A	2	4 1	x	x x	2 1 2 1 irreg	Pb-rich with P Cu	(Al/Br Si Fe Ca)	21
01A	2	5 1	x	x x	3 3 2 9 irreg	Pb-rich with Cu Mn P Zn	(Al/Br Si Fe Ca)	53
01A	2	6 1	x	x x	5 3 3 0 irreg	Pb-rich with Sb Sn Cu	(Al/Br Si Fe)	10
01A	2	7 1	x	x	12 0 7 5 irreg	Pb-rich with P Cu	(Al/Br Si Fe Ca)	21
01A	2	7 2	x	x x x	5 0 4 0 irreg	Pb-rich with P Cu Zn	(Al/Br Si Fe Ca K Ti)	22
01A	2	7 3	x	x x x	2 5 2 0 irreg	Pb-rich with P Cu	(Al/Br Si Fe Ca K Ti)	21
01A	2	7 4	x	x x x	1 3 1.3 blocky	Pb-rich with P Cu	(Al/Br Si Fe Ca K Ti)	21
01A	2	7 5	x	x x x	2 0 1 5 irreg	Pb-rich with P Cu	(Al/Br Si Fe Ca K Ti)	21
01A	2	7 6	x	x x	2 0 1 5 irreg	Pb-rich with P Cu	(Al/Br Si Fe Ca K Ti)	21
01A	2	8 1	x	x x	3 7 3 7 irreg	Pb-rich with Sb Sn Cu	(Al/Br Si Fe)	10
02A	1	1 1	x	x	20 2 15 0 blocky	Pb-rich with Sb Sn Cu	(Al/Br Si Fe)	10
02A	1	2 1	x	x	5 6 1 8	non-lead particle		
02A	1	3 1	x	x	5 2 2 1 irreg	Pb-rich with Mn P	(Fe Ca Ti)	55
02A	1	4 1	x	x x	1 6 1 0 irreg	Pb-rich with P Cu	(Al/Br Si Fe Ca Ti)	21
02A	1	5 1	x x	x x	2 0 1 7 irreg	Pb-rich with P Zn	(Al/Br Si Ca K Ti)	24
02A	1	6 1	x x	x x	2 7 1.2 irreg	Pb-rich with P Cu	(Al/Br Si Fe Ca K Ti)	21
02A	1	7 1	x x	x x	2 2 1.8 irreg	Pb-rich with Sb Sn Cu	(Al/Br Si Fe Ti)	10
02A	1	8 1	x x	x	2 5 2.2 ovoid	Pb-rich with P Cu	(Al/Br Si Fe Ca)	21
02A	2	1 1	x	x	3 8 1.4 irreg	Pb-rich with Sb Sn Cu	(Al/Br Si Fe)	10
02A	2	2 1	x	x x x	1 9 1 2 ovoid	Pb-rich with Cu Mn P Zn	(Al/Br Si Fe Ca K Ti)	53
02A	2	3 1	x	x	2 2 1 9 irreg	Pb-rich with Sb Sn P Cu Ba	(Al/Br Si Fe)	45
02A	2	4 1	x x	x	0 8 0 5 irreg	Pb-rich with Sb Sn P Cu	(Al/Br Si Fe)	16
02A	2	5 1	x	x	2 2 1 9 irreg	Pb-rich with Sb Sn Cu	(Al/Br Si Fe)	10
02A	2	6 1	x x	x	5 2 4 2 irreg	Pb-rich with P Cu	(Al/Br Si Fe Ca)	21
02A	2	7 1	x	x	0 8 0 7 irreg	Pb-rich with Sb Cu	(Al/Br Si Fe)	11
03A	1	1 1	x	x	2 3 2 7 irreg	Pb-rich with P Zn	(Al/Br Si Fe Ca)	24
03A	1	2 1	x	x	0 9 0 7 blocky	Pb-rich with P Cu		21
03A	1	3 1	x x	x	3 9 2 7 irreg	Pb-rich with P Cu	(Al/Br Si Fe Ca K)	21
03A	1	4 1	x	x	2 1 0 6 elongate	Pb-rich with Sb Sn Cu	(Al/Br Si Fe)	10
03A	1	5 1	x	x x x	1 6 1 5 irreg	Pb-rich with P Cu	(Al/Br Si Fe Ca K Ti)	21

# 2.1. Summary of IPA Results of Soil Litter in the Westgate Trailer Park (continued)

Sample No	Set No	Particle No	Major Elements			Minor Elements																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																
			Pb	Sb	Sn	P	Al	Si	Ca	Mn	Fe	K	Tl	Cu	Zn	Cl																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																						
03A	1	6.1	x																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																			

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## 2.1. Summary of IPA Results of Soil Litter in the Westgate Trailer Park (continued)

...Table Columns Continued from last page

Sample No	SEM Set No	Particle No	T	Pb	Sb	Sn	P	Tr	a	c	e	E	l	e	m	e	n	t	s	Long Diam (μm)	Perp Diam (μm)	Shape	Particle Class	Particle ID
03A	1	6.1										x								2.1	1.4	irreg	Pb-rich with P Cu (Ca)	21
03A	1	7.1										x								1.0	0.6	irreg	Pb-rich with P Cu (Al/Br Si Fe Ca K Ti)	21
03A	2	1.1										x								2.7	2.2	irreg	Pb-rich with Cu Mn P Zn (Al/Br Si Fe Ca K Ti)	53
03A	2	2.1																		1.0	0.9	irreg	Pb-rich with Sb Sn Cu (Al/Br Si Fe Ti)	10
03A	2	3.1																		1.7	1.1	irreg	Pb-rich with Sb Sn P Cu (Al/Br Si Fe Ti)	16
03A	2	4.1																		3.0	1.8	irreg	Pb-rich with Sb Sn Cu (Al/Br Si Fe Ti)	10
03A	2	5.1																		1.5	1.0	irreg	Pb-rich with Sb Sn Cu (Al/Br Si Fe)	10
03A	2	6.1																		1.5	1.0	irreg	Pb-rich with P Cu (Al/Br Si Fe Ca K Ti)	21
04A	2	1.1																		1.2	1.0	irreg	Pb-rich with Cu Zn (Al/Br Si Fe Ca K)	23
04A	2	2.1																		3.2	1.5	blocky	Pb-rich with P (Al/Br Si Fe Ca Ti)	31
04A	2	3.1																		2.0	1.3	blocky	Pb-rich with Sb Sn Cu (Al/Br Si Fe Ti)	10
04A	2	4.1																		3.6	1.6	platey	Pb-rich with Zn Pb (Al/Br Si Fe)	80
04A	2	5.1																		1.2	1.1	blocky	Pb-rich with P Cu (Al/Br Si Fe Ca K Ti)	21
04A	2	6.1																		3.2	2.4	irreg	Pb-rich with Sb Sn P Cu (Al/Br Si Fe)	16
04A	2	7.1																		2.3	1.9	irreg	Pb-rich with Sb Sn P Cu (Al/Br Si Fe Ti)	16
04A	2	8.1																		0.8	0.6	irreg	Pb-rich with Sb Sn P Cu (Al/Br Si Fe K Ca)	16
04A	2	9.1																		7.7	5.7	irreg	Pb-rich with Mn P Cu (Al/Br Si Fe Ca K Ti)	54
04A	2	10.1																		0.8	0.7	irreg	Pb-rich with P Cu (Al/Br Si Fe Ca K Ti)	21
04A	2	11.1																		2.6	2.0	irreg	Pb-rich with Sb Sn Cu (Al/Br Si Fe)	10
05A	1	1.1																		11.0	5.6	cluster of spheroids	Pb-rich with P Cu Zn (Al/Br Si Fe Ca)	22
05A	1	2.1																		4.0	3.3	irreg	Pb-rich with Sb Sn Cu	10
05A	1	3.1																		2.2	1.2	irreg	Pb-rich with P Cu (Al/Br Si Fe Ca K Ti)	21
05A	1	4.1																		1.2	0.8	irreg	Pb-rich with P (Al/Br Si Fe Ca K)	31
05A	1	5.1																		5.2	4.4	spheroid	Pb-rich with P Cu (Si Fe Ca)	21
05A	1	6.1																		1.6	1.0	irreg	Pb-rich with P Cu (Fe Ca)	21
05A	1	7.1																		1.5	1.0	irreg	Pb-rich with P Cu (Al/Br Si Fe Ca K Ti)	21
05A	1	8.1																		2.2	1.7	irreg	Pb-rich with P Cu (Ca)	21
05A	1	9.1																		1.4	0.8	irreg	Pb-rich with P Cu (Al/Br Si Fe Ca K Ti)	21
05A	1	10.1																		1.5	1.5	blocky	Pb-rich with P Cu (Al/Br Fe Ca Ti)	21
05A	2	1.1																		2.1	1.7	irreg	Pb-rich with P Cu (Al/Br Si Fe Ca K)	21
05A	2	2.1																		1.7	1.7	irreg	Pb-rich with Sb Sn P Cu (Al/Br Si Fe)	16
05A	2	3.1																		1.0	0.7	irreg	Pb-rich with P Cu (Al/Br Si Fe Ca K Ti)	21
05A	2	4.1																		1.7	0.7	irreg	Pb-rich with P Cu (Al/Br Si Fe Ca K)	21
05A	2	5.1																		1.4	1.2	irreg	Pb-rich with P Cu (Al/Br Si Fe Ca K Ti)	21
05A	2	6.1																		1.9	1.0	irreg	Pb-rich with P Cu (Al/Br Si Fe Ca K)	21
05A	2	7.1																		3.0	1.8	irreg	Pb-rich with P Cu (Al/Br Si Fe Ca K Ti)	21
05A	2	8.1																		3.6	1.7	irreg	Pb-rich with Sb Sn Cu (Al/Br Si Fe)	10
05A	2	9.1																		2.0	1.1	irreg	Pb-rich with P Cu (Al/Br Si Fe Ca K Ti)	21
05A	2	10.1																		0.8	0.7	blocky	Pb-rich with Sb Sn P Cu (Al/Br Si Fe Ti)	16
05A	2	10.2																		2.2	1.2	irreg	Pb-rich with P Cu (Al/Br Si Fe Ca K Ti)	21

# 2.1. Summary of IPA Results of Soil Litter in the Westgate Trailer Park (continued)

Sample No	Set No	Particle No	Major Elements										Minor Elements										Trace Elements										
			Br										Br										Br										
			Pb	Sb	Sn	P	Al	Si	Ca	Mn	Fe	K	Ti	Cu	Zn	Cl	Pb	Sb	Sn	P	Al	Si	Ca	Mn	Fe	K	Ti	Cu	Zn	Cl	Cr	Ni	S
05A	2	11	1	x			x	x																									
05A	2	12	1	x			x	x																									
07A	2	1	1	x	x	x	x	x																									
07A	2	2	1	x	x	x																											
07A	2	3	1	x			x	x	x																								
07A	2	4	1	x			x	x	x																								
07A	2	5	1	x			x	x	x																								
07A	2	6	1	x			x	x	x																								
07A	2	7	1	x																													
08A	2	1	1	x			x	x																									
08A	2	2	1	x			x	x																									
08A	2	3	1	x			x	x																									
08A	2	4	1	x			x	x																									
08A	2	5	1	x			x	x																									
08A	2	6	1	x			x	x																									
08A	2	7	1	x			x	x																									
08A	2	8	1	x			x	x																									
08A	2	9	1	x			x	x																									
08A	2	10	1	x			x	x																									
08A	2	11	1	x			x	x																									
08A	2	12	1	x			x	x																									
08A	2	12	2	x			x	x																									
08A	2	12	3	x			x	x																									
10A	2	1	1	x			x	x																									
10A	2	2	1	x			x	x																									
10A	2	3	1	x			x	x																									
10A	2	3	2	x			x	x																									
10A	2	4	1	x			x	x																									
13A	2	1	1	x			x	x																									
13A	2	2	1	x			x	x																									
13A	2	3	1	x			x	x																									
13A	2	4	1	x			x	x																									
13A	2	5	1	x			x	x																									
13A	2	6	1	x			x	x																									
13A	2	7	1	x			x	x																									
13A	2	8	1	x			x	x																									
13A	2	9	1	x			x	x																									
13A	2	10	1	x			x	x																									
13A	2	11	1	x			x	x																									
15A	2	1	1	x			x	x																									

Table Columns Continued on next page...

Sample No	SEM Set No	Particle No	Particle Class			Long Perp Diam (μm)	Shape	Particle Class	Particle ID
			Pb	Sb	Sn				
Particle Class									
Particle ID									
05A	2	11	1	1	1	1	1	1	1
05A	2	12	1	1	1	1	1	1	1
07A	2	1	1	1	1	1	1	1	1
07A	2	2	1	1	1	1	1	1	1
07A	2	3	1	1	1	1	1	1	1
07A	2	4	1	1	1	1	1	1	1
07A	2	5	1	1	1	1	1	1	1
07A	2	6	1	1	1	1	1	1	1
07A	2	7	1	1	1	1	1	1	1
08A	2	1	1	1	1	1	1	1	1
08A	2	2	1	1	1	1	1	1	1
08A	2	3	1	1	1	1	1	1	1
08A	2	4	1	1	1	1	1	1	1
08A	2	5	1	1	1	1	1	1	1
08A	2	6	1	1	1	1	1	1	1
08A	2	7	1	1	1	1	1	1	1
08A	2	8	1	1	1	1	1	1	1
08A	2	9	1	1	1	1	1	1	1
08A	2	10	1	1	1	1	1	1	1
08A	2	11	1	1	1	1	1	1	1
08A	2	12	1	1	1	1	1	1	1
08A	2	12	3	1	1	1	1	1	1
10A	2	1	1	1	1	1	1	1	1
10A	2	2	1	1	1	1	1	1	1
10A	2	3	1	1	1	1	1	1	1
10A	2	3	2	1	1	1	1	1	1
10A	2	4	1	1	1	1	1	1	1
13A	2	1	1	1	1	1	1	1	1
13A	2	2	1	1	1	1	1	1	1
13A	2	3	1	1	1	1	1	1	1
13A	2	4	1	1	1	1	1	1	1
13A	2	5	1	1	1	1	1	1	1
13A	2	6	1	1	1	1	1	1	1
13A	2	7	1	1	1	1	1	1	1
13A	2	8	1	1	1	1	1	1	1
13A	2	9	1	1	1	1	1	1	1
13A	2	10	1	1	1	1	1	1	1
13A	2	11	1	1	1	1	1	1	1
15A	2	1	1	1	1	1	1	1	1

## 2.1. Summary of IPA Results of Soil Litter in the Westgate Trailer Park (continued)

Sample No	SEM Set No	Particle Analysis														Particle Class	ID
		Pb	Sb	Sn	P	AL	Si	Br	Ca	Mn	Fe	K	Ti	Cu	Zn	Cl	S
15A	2	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
15A	2	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
15A	2	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x

Table Columns Continued below...

## ...Table Columns Continued from above

Sample No	SEM Set No	Particle Analysis														Particle Class	ID
		Pb	Sb	Sn	P	AL	Si	Br	Ca	Mn	Fe	K	Ti	Cu	Zn	Cl	S
15A	2	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
15A	2	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
15A	2	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x



## 2.2. Summary of IPA Results of Attic Dust in the Westgate Trailer Park

Sample No	Set No	SEM	Particle Major Elements										Particle Minor Elements																	
			Pb	Sb	Sn	P	Al	Si	Ca	Mn	Fe	K	Ti	Cu	Zn	Cl	S	Br	Ba	Al	Si	Ca	Mn	Fe	K	Ti	Cu	Zn	Cl	S
096	1		1	1																										
096	1		2	1																										
096	1		3	1																										
096	1		4	1																										
096	1		5	1																										
096	1		6	1																										
096	1		7	1																										
096	1		8	1																										
096	1		9	1																										
096	1		10	1																										
097	1		1	1																										
097	1		2	1																										
097	1		3	1																										
097	1		4	1																										
097	1		5	1																										
097	1		6	1																										
097	1		7	1																										
097	1		8	1																										
097	1		9	1																										
097	1		10	1																										
098	1		1	1																										
098	1		2	1																										
098	1		3	1																										
098	1		4	1																										
098	1		5	1																										
098	1		6	1																										
098	1		7	1																										
098	1		8	1																										
098	1		9	1																										
098	1		10	1																										

Table Columns Continued on next page...

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2.2. Summary of IPA Results of Attic Dust in the Westgate Trailer Park (continued)

...Table Columns Continued from last page

Sample No	SEM Set No	Particle		Tl	Pb	Sb	Sn	P	Ba	Al	Si	Ca	Mn	Fe	K	Ti	Cu	Zn	Cl	S	Cr	Long Diam (µm)	Perp Diam (µm)	Shape	Particle Class	Particle Class ID			
		No																											
096	1	1	1														x					3	0	1	3	irreg	Pb-rich with Cu	20	
096	1	2	1														x					2	3	1	7	irreg	Pb-rich with Cu (Al/Br Si Ca)	20	
096	1	3	1														x					1	6	1	1	irreg	Pb-rich with Cu	20	
096	1	4	1														x					8	5	7	9	ovoid	Pb-rich with Cu (Al/Br Si Fe)	20	
096	1	5	1														x					4	2	2	7	irreg	Pb-rich with Cu (Al/Br Si Fe Ca K)	20	
096	1	6	1														x					9	3	7	0	irreg	Pb-rich with Cu (Al/Br Si)	20	
096	1	7	1														x					2	6	2	1	blocky	Pb-rich with P Cu (Ca Fe)	21	
096	1	8	1														x					4	8	3	2	irreg	Pb-rich with Cu (Al/Br Si Fe Ca K)	20	
096	1	9	1														x					2	8	2	0	irreg	Pb-rich with Cu	20	
096	1	10	1														x					4	1	0	30	0	irreg	Pb-rich with Cu (Al/Br Si)	20
097	1	1	1														x					5	6	4	8	irreg	Pb-rich with Cu (Al/Br Si Fe Ca K)	20	
097	1	2	1														x					2	5	1	9	irreg	Pb-rich with Cu (K)	20	
097	1	3	1														x					9	6	4	6	irreg	Pb-rich with Cu (Al/Br Fe)	20	
097	1	4	1														x					10	3	7	6	irreg	Pb-rich with Cu (Al/Br Si Fe)	20	
097	1	5	1														x					6	0	4	2	irreg	Pb-rich with Cu (Ca)	20	
097	1	6	1														x					3	3	2	1	irreg	Pb-rich with Cu (Al/Br Si K)	20	
097	1	7	1														x					7	0	3	8	irreg	Pb-rich with Cu (Al/Br Si Ca)	20	
097	1	8	1														x					2	0	0	6	elongate	Pb-rich with Cu (Al/Br Si)	20	
097	1	9	1														x					2	3	1	1	irreg	Pb-rich with Cu (Fe Ca K)	20	
097	1	10	1														x					4	6	3	0	irreg	Pb-rich with Cu (Ca K)	20	
098	1	1	1														x					3	7	1	9	irreg	Pb-rich with Cu (Al/Br Si Fe)	20	
098	1	2	1														x					2	8	2	7	blocky	Pb-rich with Cu	20	
098	1	3	1														x					2	8	1	2	irreg	Pb-rich with Cu (Al/Br Si Fe Ca K)	20	
098	1	4	1														x					1	7	1	6	blocky	Pb-rich with Cu (Al/Br Si Fe)	20	
098	1	5	1														x					1	8	0	9	irreg	Pb-rich with Cu (Al/Br Si Fe Ca K Tl)	20	
098	1	6	1														x					8	7	4	0	irreg	Pb-rich with Cu (Al/Br Si Fe)	20	
098	1	7	1														x					1	9	1	9	blocky	Pb-rich with Cu (Al/Br Si Fe)	20	
098	1	8	1														x					4	8	4	5	irreg	Pb-rich with Cu (Al/Br Si Fe Ca K Tl)	20	
098	1	9	1														x					4	0	3	8	irreg	Pb-rich with Cu (Al/Br Si Ca)	20	
098	1	10	1														x					20	0	12	5	irreg	Pb-rich with Cu (Al/Br Si Fe Ca K)	20	

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### 3. EXIDE BATTERY FACILITY

#### 3.1. Summary of IPA Results of Soil Litter at the Exide Battery Facility

Sample No	Set No	Particle No	Major Elements										Minor Elements									
			Pb	Sb	Sn	P	Al	Si	Br	Ca	Mn	Fe	K	Ti	Cu	Zn	Cl	Cr	Ni	S		
33D	1	1	x																			
33D	1	2	x																			
33D	1	3	x																			
33D	1	4	x																			
33D	1	5	x																			
33D	1	6	x																			
33D	1	7	x																			
33D	1	8	x																			
33D	1	9	x																			
33D	1	10	x																			
33D	1	11	x																			
33D	1	12	x																			
33D	1	13	x																			
33D	1	13	x																			
33D	1	14	x																			
33D	1	15	x																			
33D	1	16	x																			
33D	1	17	x																			
33D	1	18	x																			
33D	1	19	x																			
34B	1	1	x																			
34B	1	2	x																			
34B	1	3	x																			
34B	1	4	x																			
34B	1	5	x																			
34B	1	6	x																			
34B	1	7	x																			
34B	1	8	x																			
34B	1	9	x																			
34B	1	10	x																			
34B	1	11	x																			
34B	1	12	x																			
34B	1	13	x																			
34B	1	14	x																			
34B	1	15	x																			
34B	1	16	x																			
34B	1	17	x																			
34B	1	18	x																			
34B	1	19	x																			
34B	1	20	x																			

Table Columns Continued on next page...

### 3.1. Summary of IPA Results of Soil Litter at the Exide Battery Facility (continued)

Sample No	SEM Set		Particle No	Particle			T	r	a	c	E l e m e n t s				Long Diam		Perp Shape	Particle Class	Particle ID		
	No	No		Pb	Sb	Sn					Ba	Al	Si	Ca	Mn	Fe				K	Ti
33D	1	1	1	1	1	x	x	x	x	x	x	x	x	x	2	5	1.6	ovoid	Pb-rich with Sb Sn Cu (Al/Br S1 Fe)	10	
33D	1	2	1	1	1										2	2	1.4	ovoid	Pb-rich with Cu (Al/Br S1 Fe)	20	
33D	1	3	1	1	1										1	4	1.0	irreg	Pb-rich with Sb Sn Cu (Al/Br S1 Fe)	10	
33D	1	4	1	1	1										8	5	5.6	irreg	Pb-rich with Cu (Al/Br S1 Fe)	20	
33D	1	5	1	1	1										2.5	2	5	ovoid	Pb-rich with Ba Cu (Al/Br S1 Fe)	40	
33D	1	6	1	1	1										2.0	2	0	spheroid	Pb-rich with Cu (Al/Br S1 Fe)	20	
33D	1	7	1	1	1										2.8	2	5	irreg	Pb-rich with Sb Cu (Al/Br S1 Fe)	11	
33D	1	8	1	1	1										7.3	7	3	irreg	Pb-rich with Cu (Al/Br S1 Fe)	20	
33D	1	9	1	1	1										1.7	0	9	ovoid	Pb-rich with Cu (Al/Br S1 Fe)	20	
33D	1	10	1	1	1										41.5	32	5	irreg	Pb-rich (Al/Br S1 Fe)	30	
33D	1	11	1	1	1										1	9	1.7	irreg	Pb-rich with Sb Cu (Al/Br S1 Fe)	11	
33D	1	12	1	1	1										1	7	1.5	irreg	Pb-rich with Cu (Al/Br S1 Fe)	20	
33D	1	13	1	1	1										5	2	4	irreg	Pb-rich with Cu (Al/Br S1 Fe)	20	
33D	1	13	2	1	1										5	9	3	0	irreg	Pb-rich with Cu (Al/Br S1 Fe Ca)	20
33D	1	14	1	1	1										2	4	1	5	irreg	Pb-rich with Sb Sn Cu (Al/Br S1 Fe)	10
33D	1	15	1	1	1										8	4	6	3	irreg	Pb-rich with Cu (Al/Br S1 Fe)	20
33D	1	16	1	1	1										2	3	1	7	irreg	Pb-rich with Cu (Al/Br S1 Fe)	20
33D	1	17	1	1	1										1	8	1	0	irreg	Pb-rich with Cu (Al/Br S1 Fe)	20
33D	1	18	1	1	1										1	7	1	0	ovoid	Pb-rich with Sb Sn Cu (Al/Br S1 Fe)	10
33D	1	19	1	1	1										3	5	2	3	irreg	Pb-rich with Cu (Al/Br S1 Fe)	20
34B	1	1	1	1	1										7	3	2	5	irreg	Pb-rich with P Cu (Al/Br S1 Fe Ca K)	21
34B	1	2	1	1	1										12	0	8	8	blocky	Pb-rich with P Cu	21
34B	1	3	1	1	1										1	8	1	4	irreg	Pb-rich with P Cu (Al/Br S1 Fe Ca K T1)	21
34B	1	4	1	1	1										5	0	2	5	irreg	Pb-rich with P Cu (Al/Br S1 Fe Ca)	21
34B	1	5	1	1	1										4	0	2	8	ovoid	Pb-rich with P Cu (Al/Br S1 Fe Ca)	21
34B	1	6	1	1	1										2	0	1	5	irreg	Pb-rich with P Cu (Ca)	21
34B	1	7	1	1	1										6	2	3	3	blocky	Pb-rich with P Cu (Ca)	21
34B	1	8	1	1	1										2	0	1	8	irreg	Pb-rich with Sb P Cu (Al/Br S1 Fe)	12
34B	1	9	1	1	1										1	0	0	7	irreg	Pb-rich with P Cu (Fe)	21
34B	1	10	1	1	1	</															

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3.1. Summary of IPA Results of Soil Litter at the Exide Battery Facility (continued)

SEM Sample No	Set No	Particle No	M a j o r Pb Sb Sn	E l e m e n t s Al/si Br	E l e m e n t s Ca Mn Fe K	M i n o r Ba Al/Si Br	Pb	Sb	Sn	P	E l e m e n t s Ba Al/Si Br	E l e m e n t s Ca Mn Fe K	Ti	Cu	Zn	Cl	Cr	Ni	S
35C	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
35C	1	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
35C	1	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
35C	1	4	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
35C	1	5	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
35C	1	5	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
35C	1	5	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
35C	1	6	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
35C	1	7	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
35C	1	8	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
35C	1	9	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
35C	1	10	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
35C	1	11	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
35C	1	12	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
35C	1	13	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
35C	1	14	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
35C	1	15	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
35C	1	16	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
35C	1	17	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
35C	1	18	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

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Sample No	SEM Set No	Particle		T <sub>1</sub> Pb	T <sub>2</sub> Sb	T <sub>3</sub> Sn	r <sub>1</sub> P	r <sub>2</sub> Ba	r <sub>3</sub> Al	e <sub>1</sub> Si	E <sub>2</sub> Ca	I <sub>3</sub> Mn	Fe K	m <sub>1</sub> Ti	e <sub>2</sub> Cu	n <sub>3</sub> Zn	t <sub>4</sub> s	Long Diam (μm)	Perp Diam (μm)	Shape	Particle Class			Particle Class ID	
		No	No																		Br	P	Br		Sb
35C	1	1	1			x								x				2.8	2.0	irreg	Pb-rich with Sb	Sn	Cu	10	
35C	1	2	1									x			x			2.4	1.5	irreg	Pb-rich with Sb	Sn	Cu (Fe)	10	
35C	1	3	1					x				x			x			8.9	7.5	blocky	Sn-rich with Pb	Cu (Al/Br	Si Fe)	1	
35C	1	4	1									x			x			3.2	2.0	irreg	Pb-rich with Sb	Sn	Cu (Al/Br	Si Fe)	10
35C	1	5	1					x						x	x			45.0	21.0	irreg	Pb-rich with P	Cu (Al/Br	Si)	21	
35C	1	5	2					x					x		x			3.0	2.0	irreg	Pb-rich with P	Cu (Al/Br	Si Fe)	21	
35C	1	5	3					x				x			x			2.0	2.0	spheroid	Pb-rich with Ba	P	Cu (Ca)	41	
35C	1	6	1										x			x		2.2	1.7	ovoid	Pb-rich with Cu	(Al/Br	Si Fe)	20	
35C	1	7	1									x						5.5	2.0	blocky	Pb-rich with P	(Al/Br	Si Fe	Ca)	31
35C	1	8	1					x					x		x			3.3	3.0	blocky	Pb-rich with P	Cu (Al/Br	Si Fe)	21	
35C	1	9	1					x					x					1.9	1.5	blocky	Pb-rich with Sn	(Al/Br	Si Fe)	13	
35C	1	10	1					x						x				6.8	4.4	blocky	Pb-rich with Cu	(Al/Br	Si Fe)	20	
35C	1	11	1									x			x			4.5	2.0	blocky	Pb-rich with P	Cu (Fe	Ca)	21	
35C	1	12	1					x						x				3.7	3.4	blocky	Pb-rich with Cu	(Al/Br	Si)	20	
35C	1	13	1									x			x			4.3	3.0	blocky	Sn-rich with Pb	(Al/Br	Si Fe)	2	
35C	1	14	1										x			x		4.8	3.7	irreg	Pb-rich with P	Cu (Al/Br	Si Fe)	21	
35C	1	15	1					x				x		x				3.2	2.0	irreg	Pb-rich with P	Cu (Al/Br	Si Fe	Ca)	21
35C	1	16	1					x					x		x			5.0	3.7	irreg	Sn-rich with Pb	Cu (Al/Br	Si Fe)	1	
35C	1	17	1													x		2.0	1.5	irreg	Sn-rich with Pb			2	
35C	1	18	1					x				x		x				3.9	2.5	blocky	Pb-rich with P	Cu (Al/Br	Si Fe	Ca)	21

### 3.2. Summary of IPA Results of Oxide Process Material and Dust

Sample No		Set No	Particle No	Sample Area/Type	Major Elements														Minor Elements																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																	
					Pb	Sb	Sn	P	Al	Si	Ca	Mn	Fe	K	Ti	Cu	Zn	Cl	S	Br	M	Li	N	O	R	Ca	Mn	Fe	K	Ti	Cu	Zn	Cl	Cr	Ni	S																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																
22	1	1	1	Lead Oxide Area	x																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																															</

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## 3.2. Summary of IPA Results of Exide Process Material and Dust (continued)

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Sample No	SEM Set No	Particle No	Tb	Sb	Sn	P	Ba	Al	Si	Ca	Mn	Fe	K	Ti	Cu	Zn	Cl	S	Long Perp		Particle Class	Particle Class ID				
																			Diam (μm)	Shape (μm)						
22	1	1	1												x					8	1	7	0	irreg	Pb-rich with Cu	20
22	1	2	1												x					5	8	3	8	irreg	Pb-rich with Cu (S1 Ca)	20
22	1	2	2												x					4	5	2	5	irreg	Pb-rich with Cu (S1)	20
22	1	3	1												x					3	2	3	2	irreg	Pb-rich with Cu	20
22	1	4	1												x					2	7	2	3	irreg	Pb-rich with Cu (Al/Br)	20
22	1	5	1												x					2	6	1	8	irreg	Pb-rich with Cu (Al/Br)	20
22	1	5	2												x					2	2	1	2	irreg	Pb-rich	30
22	1	6	1												x					1	7	1	5	irreg	Pb-rich with Cu (Al/Br)	20
22	1	6	2												x					1	2	1	2	irreg	Pb-rich with Cu	20
22	1	6	3												x					3	4	2	8	irreg	Pb-rich with Cu (Al/Br)	20
22	1	7	1												x					1.2	0	9	oviod	Pb-rich with Cu (Al/Br)	20	
22	1	7	2												x					2.0	1	2	irreg	Pb-rich with Cu (Al/Br)	20	
22	1	8	1												x					2	8	2	0	irreg	Pb-rich with Cu (Al/Br)	20
22	1	9	1												x					1	8	1	5	irreg	Pb-rich (Al/Br S1)	30
22	1	10	1												x					2	1	1	3	irreg	Pb-rich with Cu (Al/Br)	20
22	1	11	1												x					2	0	1	6	irreg	Pb-rich with Cu (Al/Br)	20
22	1	12	1												x					2	3	2	3	irreg	Pb-rich with Cu (Al/Br)	20
22	1	13	1												x					2	5	1	7	irreg	Pb-rich with Cu (Al/Br)	20
22	1	14	1												x					2	6	1	9	blocky	Pb-rich with Cu (Al/Br)	20
22	1	15	1												x					2	6	2	4	blocky	Pb-rich with Cu (Al/Br Ca)	20
23	1	1	1												x					2	3	1	8	irreg	Pb-rich with Cu (Al/Br)	20
23	1	2	1												x					2	6	2	0	irreg	Pb-rich with Cu (Al/Br)	20
23	1	3	1												x					3	0	1	7	irreg	Pb-rich (Al/Br)	30
23	1	4	1												x					1	9	1	8	irreg	Pb-rich with Cu (Al/Br Fe)	20
23	1	5	1												x					1	3	0	8	irreg	Pb-rich with Cu (Al/Br)	20
23	1	6	1												x					4	2	2	0	irreg	Pb-rich with Cu (Al/Br)	20
23	1	7	1												x					5	5	4	6	irreg	Pb-rich with Cu (Al/Br)	20
23	1	8	1												x					4	4	3	8	blocky	Pb-rich with Cu (Al/Br)	20
23	1	9	1												x					3	9	2	2	irreg	Pb-rich with Cu (Al/Br)	20
23	1	10	1												x					2	1	1	6	blocky	Pb-rich with Cu (Al/Br)	20
23	1	11	1												x					2	9	2	0	blocky	Pb-rich with Cu (Al/Br)	20
23	1	12	1												x					4	0	3	3	blocky	Pb-rich (Al/Br)	30
23	1	13	1												x					7	4	6	1	irreg	Pb-rich with Cu (Al/Br)	20
23	1	14	1												x					6	0	4	0	irreg	Pb-rich with Cu (Al/Br)	20
23	1	14	2												x					4	5	3	5	irreg	Pb-rich with Cu (Al/Br)	20
23	1	15	1												x					2	0	1	5	irreg	Pb-rich with Cu (Al/Br Fe Ca)	20
23	1	16	1												x					4	0	2	7	irreg	Pb-rich with Cu (Al/Br)	20
23	1	17	1												x					1	8	1	2	irreg	Pb-rich with Cu (Al/Br Fe Ca)	20
23	1	18	1												x					2	6	1	7	irreg	Pb-rich (Al/Br)	30
23	1	19	1												x					3	2	2	2	irreg	Pb-rich with Cu (Al/Br)	20



### 3.2. Summary of IPA Results of Exide Process Material and Dust (continued)

Sample No	SEM Set No	Particle No	Sample Area/Type	Major Elements												Minor Elements																		
				Pb	Sb	Sn	P	Al	Si	Ca	Mn	Fe	K	Ti	Cu	Zn	Cl	S	Br	Ba	Al	Si	Ca	Mn	Fe	K	Ti	Cu	Zn	Cl	S			
24	1	1	Lead Oxide Area	x																														
24	1	2	Lead Oxide Area	x																														
24	1	2	Lead Oxide Area	x																														
24	1	3	Lead Oxide Area	x																														
24	1	4	Lead Oxide Area	x																														
24	1	5	Lead Oxide Area	x																														
24	1	6	Lead Oxide Area	x																														
24	1	7	Lead Oxide Area	x																														
24	1	7	Lead Oxide Area	x																														
24	1	8	Lead Oxide Area	x																														
24	1	9	Lead Oxide Area	x																														
24	1	10	Lead Oxide Area	x																														
24	1	11	Lead Oxide Area	x																														
24	1	12	Lead Oxide Area	x																														
24	1	13	Lead Oxide Area	x																														
24	1	14	Lead Oxide Area	x																														
24	1	14	Lead Oxide Area	x																														
24	1	14	Lead Oxide Area	x																														
24	1	14	Lead Oxide Area	x																														
24	1	15	Lead Oxide Area	x																														
24	1	16	Lead Oxide Area	x																														
25	1	1	Grid Casting Area	x																														
25	1	1	Grid Casting Area	x																														
25	1	2	Grid Casting Area	x																														
25	1	3	Grid Casting Area	x																														
25	1	4	Grid Casting Area	x																														
25	1	5	Grid Casting Area	x																														
25	1	6	Grid Casting Area	x																														
25	1	7	Grid Casting Area	x																														
25	1	8	Grid Casting Area	x																														
25	1	9	Grid Casting Area	x																														
25	1	10	Grid Casting Area	x																														
25	1	11	Grid Casting Area	x																														
25	1	12	Grid Casting Area	x																														
25	1	13	Grid Casting Area	x																														
25	1	14	Grid Casting Area	x																														
25	1	15	Grid Casting Area	x																														
25	1	16	Grid Casting Area	x																														
25	1	17	Grid Casting Area	x																														
25	1	18	Grid Casting Area	x																														
25	1	19	Grid Casting Area	x																														

Table Columns Continued on next page...

## 3.2. Summary of IPA Results of Exide Process Material and Dust (continued)

...Table Columns Continued from last page

Sample No	SEM Set No	Particle No	T	r	a	c	e	E	l	e	m	e	n	t	s	Long Perp Diam (μm)	Shape	Particle Class	Particle Class ID
			Pb	Sb	Sn	P	Ba	Al	Si	Ca	Mn	Fe	K	Ti	Cu	Zn	Cl	Cr	
24	1	1.1																	
24	1	1.2																	
24	1	2.1																	
24	1	3.1																	
24	1	4.1																	
24	1	5.1																	
24	1	6.1																	
24	1	7.1																	
24	1	7.2																	
24	1	8.1																	
24	1	9.1																	
24	1	10.1																	
24	1	11.1																	
24	1	12.1																	
24	1	13.1																	
24	1	14.1																	
24	1	14.2																	
24	1	14.3																	
24	1	15.1																	
24	1	16.1																	
25	1	1.1																	
25	1	1.2																	
25	1	2.1																	
25	1	3.1																	
25	1	4.1																	
25	1	5.1																	
25	1	6.1																	
25	1	7.1																	
25	1	8.1																	
25	1	9.1																	
25	1	10.1																	
25	1	11.1																	
25	1	12.1																	
25	1	13.1																	
25	1	14.1																	
25	1	15.1																	
25	1	16.1																	
25	1	17.1																	
25	1	18.1																	
25	1	19.1																	

### 3.2. Summary of IPA Results of Exide Process Material and Dust (continued)

Table Columns Continued on next page...

### 3.2. Summary of IPA Results of Exide Process Material and Dust (continued)

...Table Columns Continued from last page

Sample No	SEM Set	Particle No	T	r	a	c	e	E	i	e	m	e	n	t	s	Long Diam (μm)	Perp Diam (μm)	Shape	Particle Class	Particle Class	Particle Class ID
26	1	1.1																			
26	1	2.1																			
26	1	3.1																			
26	1	4.1																			
26	1	5.1																			
26	1	6.1																			
26	1	7.1																			
26	1	8.1																			
26	1	9.1																			
26	1	10.1																			
26	1	11.1																			
26	1	12.1																			
26	1	13.1																			
26	1	14.1																			
26	1	15.1																			
26	1	16.1																			
26	1	17.1																			
26	1	18.1																			
26	1	19.1																			
26	1	20.1																			
27	1	1.1																			
27	1	2.1																			
27	1	3.1																			
27	1	4.1																			
27	1	5.1																			
27	1	6.1																			
27	1	7.1																			
27	1	8.1																			
27	1	9.1																			
27	1	10.1																			
27	1	11.1																			
27	1	12.1																			
27	1	13.1																			
27	1	14.1																			
27	1	15.1																			
27	1	16.1																			
27	1	17.1																			
27	1	18.1																			
27	1	19.1																			
27	1	20.1																			

### 3.2. Summary of IPA Results of Exide Process Material and Dust (continued)

Sample No	Set No	Particle No	Sample Area/Type	Major Elements														Minor Elements																	
				Pb	Sb	Sn	P	Al	Si	Ca	Mn	Fe	K	Ti	Cu	Zn	Cl	Pb	Sb	Sn	P	Ba	Al	Sr	Ca	Mn	Fe	K	Ti	Cu	Zn	Cl	Cr	Ni	S
21	1	1	Pasting Area	x																															
21	1	1.2	Pasting Area	x																															
21	1	2.1	Pasting Area	x																															
21	1	3.1	Pasting Area	x																															
21	1	4.1	Pasting Area	x																															
21	1	5.1	Pasting Area	x																															
21	1	6.1	Pasting Area	x																															
21	1	7.1	Pasting Area	x																															
21	1	8.1	Pasting Area	x																															
21	1	9.1	Pasting Area	x																															
21	1	10.1	Pasting Area	x																															
21	1	11.1	Pasting Area	x																															
21	1	12.1	Pasting Area	x																															
21	1	13.1	Pasting Area	x																															
21	1	14.1	Pasting Area	x																															
21	1	15.1	Pasting Area	x																															
21	1	16.1	Pasting Area	x																															
21	1	16.2	Pasting Area	x																															
21	1	17.1	Pasting Area	x																															
21	1	18.1	Pasting Area	x																															
28	1	1.1	Pasting Area	x																															
28	1	2.1	Pasting Area	x																															
28	1	3.1	Pasting Area	x																															
28	1	4.1	Pasting Area	x																															
28	1	5.1	Pasting Area	x																															
28	1	5.2	Pasting Area	x																															
28	1	6.1	Pasting Area	x																															
28	1	7.1	Pasting Area	x																															
28	1	8.1	Pasting Area	x																															
28	1	9.1	Pasting Area	x																															
28	1	10.1	Pasting Area	x																															
28	1	11.1	Pasting Area	x																															
28	1	12.1	Pasting Area	x																															
28	1	13.1	Pasting Area	x																															
28	1	14.1	Pasting Area	x																															
28	1	15.1	Pasting Area	x																															
28	1	16.1	Pasting Area	x																															
28	1	17.1	Pasting Area	x																															
28	1	18.1	Pasting Area	x																															
28	1	19.1	Pasting Area	x																															

Table Columns Continued on next page....

Sample No	SEM Set No	Particle No	T r a c e						E l e m e n t s							Long Perp Diam (μm)		Particle Class	Particle ID				
			Pb	Sb	Tl	Sn	P	Ba	Al	Si	Ca	Mn	Fe	K	Ti	Cu	Zn			Cr	Diam	Shape	
21	1	1	1	1		X							X				2	2	0	irreg	Pb-rich with Cu (Al/Br)	20	
21	1	1	2			X							X				1	3	1	0	irreg	Pb-rich with Cu (Al/Br Fe)	20
21	1	2	1			X							X				1	6	1	2	irreg	Pb-rich with Cu (Al/Br Fe)	20
21	1	3	1			X							X				2	0	1	1	ovoid	Pb-rich with Cu (Al/Br)	20
21	1	4	1			X							X				2	2	2	1	irreg	Pb-rich with Cu (Al/Br)	20
21	1	5	1			X							X				2	5	2	5	irreg	Pb-rich with Cu (Al/Br)	20
21	1	6	1			X							X				2	0	1	1	irreg	Pb-rich with Cu (Al/Br Fe)	20
21	1	7	1			X							X				2	0	1	8	irreg	Pb-rich (Al/Br)	30
21	1	8	1			X							X				3	8	3	2	irreg	Pb-rich with Cu (Al/Br Fe)	20
21	1	9	1			X							X				2	9	2	3	irreg	Pb-rich with Cu (Al/Br)	20
21	1	10	1			X							X				4	0	2	2	irreg	Pb-rich with Cu (Al/Br Fe)	20
21	1	11	1			X							X				1	8	1	0	irreg	Pb-rich (Al/Br Fe)	30
21	1	12	1			X							X				1	4	1	2	irreg	Pb-rich with Cu (Al/Br)	20
21	1	13	1			X							X				3	8	1	8	irreg	Pb-rich with Cu (Al/Br Fe)	20
21	1	14	1			X							X				4	2	2	8	irreg	Pb-rich with Cu (Al/Br Si Fe)	20
21	1	15	1			X							X				3	5	3	4	irreg	Pb-rich with Cu (Al/Br Fe)	20
21	1	16	1			X							X				5	2	3	0	irreg	Pb-rich with Cu (Al/Br Si)	20
21	1	16	2			X							X				3	2	1	4	irreg	Pb-rich with Cu (Al/Br Si)	20
21	1	17	1			X							X				5	5	4	0	ovoid	Pb-rich with Cu (Al/Br Fe)	20
21	1	18	1			X							X				1	4	1	2	irreg	Pb-rich with Cu (Al/Br)	20
28	1	1	1			X							X				2	5	2	0	blocky	Pb-rich with Cu (Al/Br Si)	20
28	1	2	1			X							X				5	3	3	5	blocky	Pb-rich with Cu (Al/Br)	20
28	1	3	1			X							X				1	2	1	1	irreg	Pb-rich with Cu Zn (Al/Br Si Fe K)	23
28	1	4	1			X							X				4	2	3	5	irreg	Pb-rich with Cu	20
28	1	5	1			X							X				2	9	2	5	irreg	Pb-rich with Cu (Al/Br)	20
28	1	5	2			X							X				2	5	2	2	irreg	Pb-rich with Cu (Al/Br Ca)	20
28	1	6	1			X							X				3	0	1	7	irreg	Pb-rich with Cu (Al/Br)	20
28	1	7	1			X							X				1	5	1	2	irreg	Pb-rich with Cu (Al/Br)	20
28	1	8	1			X							X				4	0	2	3	irreg	Pb-rich with	

### 3.2. Summary of IPA Results of Exide Process Material and Dust (continued)

Sample No	Set No	Particle No	Sample Area/Type	Major Elements										Minor Elements																					
				Pb	Sb	Sn	P	Al	Si	Ca	Mn	Fe	K	Ti	Cu	Zn	Cl	Pb	Sb	Sn	P	Ba	Al	Si	Ca	Mn	Fe	K	Ti	Cu	Zn	Cl	Cr	Ni	S
29	1	1	Pasting Area	x																															
29	1	2	Pasting Area	x																															
29	1	3	Pasting Area	x																															
29	1	4	Pasting Area	x																															
29	1	5	Pasting Area	x																															
29	1	6	Pasting Area	x																															
29	1	6	Pasting Area	x																															
29	1	7	Pasting Area	x																															
29	1	8	Pasting Area	x																															
29	1	9	Pasting Area	x																															
29	1	10	Pasting Area	x																															
29	1	11	Pasting Area	x																															
29	1	12	Pasting Area	x																															
29	1	12	Pasting Area	x																															
29	1	13	Pasting Area	x																															
36	1	1	Ground Debris	x																															
36	1	2	Ground Debris	x																															
36	1	3	Ground Debris	x																															
36	1	4	Ground Debris	x																															
36	1	5	Ground Debris	x																															
36	1	6	Ground Debris	x																															
36	1	7	Ground Debris	x																															
36	1	8	Ground Debris	x																															
36	1	9	Ground Debris	x																															
36	1	10	Ground Debris	x																															
36	1	11	Ground Debris	x																															
36	1	12	Ground Debris	x																															
36	1	13	Ground Debris	x																															
36	1	14	Ground Debris	x																															
37	1	1	Ground Debris	x																															
37	1	2	Ground Debris	x																															
37	1	3	Ground Debris	x																															
37	1	4	Ground Debris	x																															
37	1	5	Ground Debris	x																															

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## 3.2. Summary of IPA Results of Oxide Process Material and Dust (continued)

...Table Columns Continued from last page

Sample No	SEM Set No	Particle No	Particle Class										Particle Class	Particle ID											
			Pb	Sb	Ti	Al	P	Ba	Al	Si	Ca	Mn			Fe	K	Ti	Cu	Zn	Cl	Cr	Long Diam (μm)	Perp Diam (μm)	Shape	
29	1	1	1																20	0	17	5	blocky	Pb-rich with Ba Cu (Al/Br)	40
29	1	2	1																19	2	12	3	irreg	Pb-rich	30
29	1	3	1																53	0	35	0	blocky	Pb-rich with Ba	42
29	1	4	1																6	0	4	4	irreg	Pb-rich (Al/Br)	30
29	1	5	1																2	0	1	7	irreg	Pb-rich	30
29	1	6	1																3	0	2	6	irreg	Pb-rich (Al/Br)	30
29	1	6	2																1	7	1	5	blocky	Pb-rich (Al/Br)	30
29	1	7	1																1	9	1	6	irreg	Pb-rich (Al/Br)	30
29	1	8	1																2	7	1	5	blocky	Pb-rich	30
29	1	9	1																2	4	2	0	blocky	Pb-rich with Ba (Al/Br)	42
29	1	10	1																2	5	2	0	blocky	Pb-rich with Ba (Al/Br)	42
29	1	11	1																3	8	1	8	irreg	Pb-rich with Ba	42
29	1	12	1																2	0	2	0	irreg	Pb-rich with Ba	42
29	1	12	2																2	0	1	8	irreg	Pb-rich with Ba	42
29	1	13	1																2	8	2	0	irreg	Pb-rich	30
36	1	1	1																8	3	4	0	blocky	Pb-rich with Cu (Al/Br Si Fe)	20
36	1	2	1																8	2	7	8	blocky	Pb-rich (Al/Br Si Fe)	30
36	1	3	1																2	8	1	8	irreg	Pb-rich with Cu	20
36	1	3	2																3	0	2	0	irreg	Pb-rich with P	31
36	1	4	1																4	2	3	5	irreg	Pb-rich with Cu (Al/Br Fe)	20
36	1	5	1																7	7	4	5	blocky	Pb-rich (Al/Br Si)	30
36	1	6	1																7	5	3	9	irreg	Pb-rich with Cu (Al/Br Fe K)	20
36	1	7	1																4	5	2	7	irreg	Pb-rich (Al/Br Fe)	30
36	1	8	1																6	8	4	0	blocky	Pb-rich (Al/Br)	30
36	1	9	1																4	5	4	3	blocky	Pb-rich (Al/Br Si Fe)	30
36	1	10	1																6	0	5	2	blocky	Pb-rich with Cu (Al/Br Fe Ca)	20
36	1	11	1																7	0	5	5	blocky	Pb-rich with Cu (Al/Br Fe Ca)	20
36	1	12	1																4	7	4	5	spheroid	Pb-rich (Al/Br Si Fe)	30
36	1	13	1																3	0	2	0	irreg	Pb-rich (Al/Br Fe)	30
36	1	14	1																11	0	8	5	blocky	Pb-rich with P Cu (Al/Br Si Fe Ca)	21
37	1	1	1																3	2	0	blocky	Pb-rich with Cu (Al/Br Si Fe)	20	
37	1	2	1																5	7	2	8	blocky	Pb-rich with Cu (Al/Br Si Fe)	20
37	1	3	1																6	2	4	5	irreg	Pb-rich with Cu (Al/Br Si Fe)	20
37	1	4	1																2	3	1	7	blocky	Pb-rich with Sb Sn Cu (Al/Br Si Fe Tl)	10
37	1	5	1																14	8	11	3	blocky	Pb-rich with Cu (Al/Br Si Fe)	20
37	1	6	1																3	3	2	5	blocky	Pb-rich with Sb Sn Cu (Al/Br Si)	10
37	1	7	1																5	3	4	9	blocky	Pb-rich with P Cu (Al/Br Si Fe Ca)	21
37	1	8	1																3	7	1	8	irreg	Pb-rich with Sb Sn Cu (Al/Br Si Fe)	10
37	1	9	1																1	6	1	4	irreg	Pb-rich with Sb Cu (Al/Br Si Fe)	11
37	1	10	1																3	3	1	9	irreg	Pb-rich with Sb Sn P Cu(Al/Br Si Fe)	16



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3.2. Summary of IPA Results of Exide Process Material and Dust (continued)

Sample No		Set No	Particle No	Sample Area/Type	Major Elements												Minor Elements																		
					Pb	Sb	Sn	P	Al	Si	Ca	Mn	Fe	K	Ti	Cu	Zn	Cl	S	Pb	Sb	Sn	P	Ba	Al	Si	Ca	Mn	Fe	K	Ti	Cu	Zn	Cl	S
					Br												Br																		
37	1	11	1	Ground Debris	x																														
37	1	12	1	Ground Debris	x																														
37	1	13	1	Ground Debris	x																														
37	1	14	1	Ground Debris	x																														
37	1	15	1	Ground Debris	x																														
37	1	16	1	Ground Debris	x																														
37	1	17	1	Ground Debris	x																														
37	1	18	1	Ground Debris	x																														
37	1	19	1	Ground Debris	x																														
37	1	20	1	Ground Debris	x																														
38	1	1	1	Ground Debris	x																														
38	1	2	1	Ground Debris	x																														
38	1	3	1	Ground Debris	x																														
38	1	4	1	Ground Debris	x																														
38	1	5	1	Ground Debris	x																														
38	1	6	1	Ground Debris	x																														
38	1	7	1	Ground Debris	x																														
38	1	8	1	Ground Debris	x																														
38	1	9	1	Ground Debris	x																														
38	1	10	1	Ground Debris	x																														
38	1	11	1	Ground Debris	x																														
38	1	12	1	Ground Debris	x																														
38	1	13	1	Ground Debris	x																														
38	1	14	1	Ground Debris	x																														
40	1	1	1	Ground Debris	x																														
40	1	2	1	Ground Debris	x																														
40	1	2	2	Ground Debris	x																														
40	1	3	1	Ground Debris	x																														
40	1	4	1	Ground Debris	x																														
40	1	5	1	Ground Debris	x																														
40	1	6	1	Ground Debris	x																														
40	1	7	1	Ground Debris	x																														
40	1	8	1	Ground Debris	x																														
40	1	9	1	Ground Debris	x																														
40	1	10	1	Ground Debris	x																														
40	1	11	1	Ground Debris	x																														
40	1	11	2	Ground Debris	x																														
40	1	12	1	Ground Debris	x																														
40	1	13	1	Ground Debris	x																														
40	1	14	1	Ground Debris	x																														

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### 3.2. Summary of IPA Results of Exide Process Material and Dust (continued)

...Table Columns Continued from last page

Sample No	SEM Set No	Particle No	Particle Class																Particle Class ID								
			Ti	Pb	Sb	Sn	P	Br	Al	Si	Ca	Mn	Fe	K	Ti	Cu	Zn	Cl		S	Cr	Long Diam (μm)	Perp Diam (μm)	Shape			
37	1	11						X	X		X			X		X					10	0	6	0	irreg	Pb-rich with Cu (Al/Br Si Fe)	20
37	1	12						X	X		X			X		X					4	7	2	8	irreg	Pb-rich with Cu (Al/Br)	20
37	1	13				X			X	X		X		X		X					4	1	3	0	blocky	Pb-rich with Sb Sn Cu (Al/Br Si Fe)	10
37	1	14							X	X		X		X		X					40	0	28	0	blocky	Pb-rich with Sn (Al/Br Si Fe)	13
37	1	15							X	X		X		X		X					11	8	8	0	irreg	Pb-rich with Cu (Al/Br Si)	20
37	1	16					X		X	X		X		X		X					5	3	4	3	irreg	Pb-rich with Sb Sn P Cu (Al/Br Si Fe)	16
37	1	17					X		X	X		X		X		X					2	2	1	6	irreg	Pb-rich with P Cu (Al/Br Si Fe Ti)	21
37	1	18							X	X		X		X		X					4	3	2	8	blocky	Pb-rich with Cu (Al/Br Si Fe)	20
37	1	19				X			X	X		X		X		X					5	4	2	9	irreg	Pb-rich with Sb Sn Cu (Al/Br Si Fe)	10
37	1	20							X	X		X		X		X					3	2	2	2	blocky	Pb-rich with Cu (Al/Br Si Fe)	20
38	1	1							X	X		X		X		X					8	5	5	6	irreg	Pb-rich (Al/Br Ca)	30
38	1	2							X	X		X		X		X					10	2	8	2	irreg	Pb-rich with Cu (Al/Br Si Fe)	20
38	1	3						X	X	X		X		X		X					2	5	2	5	irreg	Pb-rich with Sb Cu (Al/Br Si Fe)	11
38	1	4							X	X		X		X		X					5	2	3	5	irreg	Pb-rich with Cu (Al/Br Si Fe)	20
38	1	5							X	X		X		X		X					3	4	1	8	irreg	Pb-rich with Cu (Al/Br Si Fe)	20
38	1	6							X	X		X		X		X					6	1	4	4	blocky	Pb-rich with Cu (Al/Br Si Fe)	20
38	1	7							X	X		X		X		X					3	7	2	8	blocky	Pb-rich with Cu (Al/Br)	20
38	1	8							X	X		X		X		X					4	2	2	2	blocky	Pb-rich with Cu (Fe K)	20
38	1	9					X		X	X		X		X		X					3	8	3	2	irreg	Pb-rich with Sb Sn Cu (Al/Br Si Fe)	10
38	1	10							X	X		X		X		X					1	9	1	3	blocky	Pb-rich with Cu (Al/Br Si Fe Ca)	20
38	1	11							X	X		X		X		X					3	7	2	7	irreg	Pb-rich with Cu (Al/Br Si Fe)	20
38	1	12							X	X		X		X		X					6	5	5	0	spheroid	Pb-rich with Cu (Al/Br Si Fe)	20
38	1	13							X	X		X		X		X					2	2	1	7	irreg	Pb-rich (Al/Br Si Fe)	30
38	1	14							X	X		X		X		X					4	0	3	6	irreg	Pb-rich with Cu (Al/Br Si Fe)	20
40	1	1							X	X		X		X		X					4	3	3	0	irreg	Pb-rich (Al/Br Si Fe K)	30
40	1	2							X	X		X		X		X					1	6	1	2	irreg	Pb-rich with Cu (Al/Br Si Fe)	20
40	1	2							X	X		X		X		X					2	0	1	4	irreg	Pb-rich with Cu (Al/Br Si Fe)	30
40	1	3							X	X		X		X		X					1	7	0	9	irreg	Pb-rich (Al/Br Si Fe)	30
40	1	4							X	X		X		X		X					1	8	1	7	irreg	Pb-rich (Al/Br Si Fe)	30
40	1	5					X							X							3	3	2	3	blocky	Pb-rich with P (Al/Br Si Fe)	31
40	1	6												X							2	8	1	5	irreg	Pb-rich with Cu (Al/Br Si Fe)	20
40	1	7							X	X		X		X		X					4	0	1	7	irreg	Pb-rich (Al/Br Si Fe)	30
40	1	8							X	X		X		X		X					4	3	3	0	blocky	Pb-rich (Al/Br Si Fe)	30
40	1	9							X	X		X		X		X					3	0	2	6	irreg	Pb-rich with Cu (Al/Br Si Fe)	20
40	1	10							X	X		X		X		X					3	5	2	6	irreg	Pb-rich with Cu (Al/Br Si Fe)	20
40	1	11								X		X		X		X					1	5	1	3	blocky	Pb-rich (Al/Br Si Fe)	30
40	1	11							X	X		X		X		X					1	2	0	9	blocky	Pb-rich (Al/Br Si Fe)	30
40	1	12							X	X		X		X		X					3	8	3	2	irreg	Pb-rich (Al/Br Si Fe)	30
40	1	13							X	X		X		X		X					10	0	5	5	blocky	Pb-rich (Al/Br Si Fe)	30
40	1	14							X	X		X		X		X					6	1	3	9	irreg	Pb-rich with Cu (Al/Br Si Fe)	20

Table Columns Continued on next page...

## 3.2. Summary of IPA Results of Exide Process Material and Dust (continued)

...Table Columns Continued from last page

Sample No	SEM Set No	Particle No	Particle			Tl	Pb	Sb	Sn	P	Ba	Al	Si	Ca	Mn	Fe	K	Ti	Cu	Zn	Cl	S	Long Perp		Particle Class	Particle Class ID			
			Br	Cr	Diam (μm)																		Diam (μm)						
40	1	15	1																				7	2	4	2	blocky	Pb-rich (Al/Br Si Fe Ti)	30
40	1	16	1								X	X											2	1	1	9	irreg	Pb-rich (Al/Br Si)	30
40	1	17	1												X				X				9	3	8	0	irreg	Pb-rich with Cu (Al/Br Si Fe)	20
40	1	18	1							X					X				X				11	0	8	2	irreg	Pb-rich with P Cu (Al/Br Si Fe Ti)	21
31	1	1	1								X	X											2	5	1	9	irreg	Pb-rich with Cu (Al/Br Si)	20
31	1	1	2								X												4	2	3	0	irreg	Pb-rich with Ba Cu	40
31	1	1	2	1							X												4	0	3	3	blocky	Pb-rich with Cu (Al/Br)	20
31	1	1	3	1							X												3	8	2	7	blocky	Pb-rich with Cu (Al/Br)	20
31	1	1	4	1							X												5	0	4	7	irreg	Pb-rich with Cu (Al/Br)	20
31	1	1	5	1							X												4	1	3	0	irreg	Pb-rich with Cu (Al/Br)	20
31	1	1	5	2							X												3	8	2	9	irreg	Pb-rich with Cu (Al/Br)	20
31	1	1	6	1																			4	8	3	3	irreg	Pb-rich with Cu (Al/Br)	20
31	1	1	7	1							X												4	0	4	0	blocky	Pb-rich with Cu (Al/Br)	20
31	1	1	8	1							X												5	1	3	6	irreg	Pb-rich with Cu (Al/Br)	20
31	1	1	8	2							X												5	7	2	5	irreg	Pb-rich (Al/Br)	30
31	1	1	8	3							X												4	7	2	7	irreg	Pb-rich with Cu (Al/Br)	20
31	1	1	9	1							X												5	8	4	0	irreg	Pb-rich with Cu (Al/Br)	20
31	1	1	10	1							X												2	5	1	7	irreg	Pb-rich with Cu (Al/Br)	20
31	1	1	11	1							X												3	3	2	4	blocky	Pb-rich with Cu (Al/Br)	20
32	1	1	1	1							X												2	3	1	7	irreg	Pb-rich (Al/Br)	30
32	1	1	2	1																			3	5	2	6	blocky	Pb-rich with Cu	20
32	1	1	3	1							X												2	4	1	2	irreg	Pb-rich with Cu (Al/Br)	20
32	1	1	4	1							X												4	6	3	3	irreg	Pb-rich with Cu	20
32	1	1	5	1																			5	8	3	4	irreg	Pb-rich with Cu	20
32	1	1	6	1																			3	3	1	7	irreg	Pb-rich with Cu (Al/Br)	20
32	1	1	7	1							X												4	2	1	9	blocky	Pb-rich (Al/Br)	30
32	1	1	8	1							X												3	1	1	7	irreg	Pb-rich with Cu (Al/Br)	20
32	1	1	9	1							X												3	1	1	1	blocky	Pb-rich with Cu (Al/Br)	20
32	1	1	10	1							X												4	3	4	0	irreg	Pb-rich with Cu (Al/Br)	20
32	1	1	11	1																			1	5	1	3	irreg	Pb-rich (Al/Br Si)	30
32	1	1	12	1							X												2	6	1	4	irreg	Pb-rich with Cu (Al/Br)	20
32	1	1	12	2							X												2	6	1	3	irreg	Pb-rich with Ba Cu (Al/Br)	40
32	1	1	12	3							X												1	4	0	9	ovoid	Pb-rich (Al/Br)	30
32	1	1	13	1																			1	7	1	7	blocky	Pb-rich with Cu	20
32	1	1	14	1																			2	7	2	3	irreg	Pb-rich with Cu (Al/Br)	20
32	1	1	15	1							X												3	5	3	0	blocky	Pb-rich with Cu (Al/Br)	20
32	1	1	16	1							X												3	4	2	8	blocky	Pb-rich (Al/Br)	30
32	1	1	17	1							X												1	4	1	2	blocky	Pb-rich (Al/Br)	30
32	1	1	18	1							X												1	9	1	4	irreg	Pb-rich (Al/Br)	30
90	1	1	1	1							X	X											3	1	2	6	irreg	Pb-rich with Cu (Al/Br Si)	20

## 3.2. Summary of IPA Results of Exide Process Material and Dust (continued)

SEM Sample No	Set No	Particle No	Sample Area/Type	Major Elements														Particle Class	ID
				Pb	Sb	P	Al	Si	Ca	Mn	Fe	K	Ti	Cu	Zn	Cl	Br		
90	1	2.1	Baghouse	x															
90	1	2.2	Baghouse	x															
90	1	3.1	Baghouse	x															
90	1	3.2	Baghouse	x															
90	1	4.1	Baghouse	x															
90	1	5.1	Baghouse	x															
90	1	6.1	Baghouse	x															
90	1	7.1	Baghouse	x															
90	1	8.1	Baghouse	x															
90	1	9.1	Baghouse	x															
90	1	10.1	Baghouse	x															
90	1	11.1	Baghouse	x															
90	1	12.1	Baghouse	x															
90	1	13.1	Baghouse	x															

Table Columns Continued below...

...Table Columns Continued from above

SEM Sample No	Set No	Particle No	Sample Area/Type	Major Elements														Particle Class	ID
				Pb	Sb	P	Al	Si	Ca	Mn	Fe	K	Ti	Cu	Zn	Cl	Br		
90	1	2.1																	
90	1	2.2																	
90	1	3.1																	
90	1	3.2																	
90	1	4.1																	
90	1	5.1																	
90	1	6.1																	
90	1	7.1																	
90	1	8.1																	
90	1	9.1																	
90	1	10.1																	
90	1	11.1																	
90	1	12.1																	
90	1	13.1																	

### 3.3.3. Summary of IPA Results of Air Filters at the Exide Battery Facility

Table Columns Continued on next page...

### 3.3. Summary of IPA Results of Air Filters at the Exide Battery Facility (continued)

Sample No	SEM Set No	Particle No	Tl	Pb	Sb	Sn	Zr	P	Ba	Al/Si Br	E Ca	Mn Fe	Ti K	Cu Zn	Cr S Cl	Long Diam (μm)	Perp Diam (μm)	Shape	Particle Class	Particle ID
F14	1	1	1						x			x				1.8	1.5	irreg	Pb-rich (Al/Br Fe)	30
F14	1	2	1										x			4.6	4.0	blocky	Pb-rich with Cu	20
F14	1	3	1													5.0	4.0	blocky	Pb-rich	30
F14	1	4	1							x						1.7	1.5	ovoid	Pb-rich (Al/Br)	30
F14	1	5	1							x						3.5	2.5	irreg	Pb-rich (Al/Br)	30
F14	1	6	1									x				5.6	2.5	irreg	Pb-rich (Fe)	30
F14	1	7	1					x				x				2.2	1.0	irreg	Pb-rich with P Cu (Fe)	21
F14	1	8	1													1.8	1.0	irreg	Pb-rich	30
F14	1	9	1													3.0	2.3	irreg	Pb-rich	30
F14	1	10	1													1.7	1.2	irreg	Pb-rich	30
F49	1	1	1													2.0	1.3	ovoid	Pb-rich	30
F49	1	2	1									x				3.6	2.0	irreg	Pb-rich (Fe K)	30
F49	1	3	1									x				3.4	1.9	irreg	Pb-rich (K)	30
F49	1	4	1									x				3.7	3.5	irreg	Pb-rich (K)	30
F49	1	5	1													3.3	2.5	irreg	Pb-rich	30
F49	1	6	1													3.7	2.7	irreg	Pb-rich	30
F49	1	7	1										x			1.9	1.7	irreg	Pb-rich (K)	30
F49	1	8	1													2.3	1.5	irreg	Pb-rich	30
F49	1	9	1													2.7	1.9	irreg	Pb-rich	30
F56	1	1	1										x			2.0	1.4	ovoid	Pb-rich (K)	30
F56	1	2	1													5.0	4.5	irreg	Pb-rich with Cu	20
F56	1	3	1													2.1	0.9	irreg	Pb-rich	30
F56	1	4	1													3.0	2.7	irreg	Pb-rich	30
F56	1	5	1													2.0	1.1	irreg	Pb-rich	30
F56	1	6	1									x				1.5	1.1	irreg	Pb-rich (K)	30
F56	1	7	1													2.0	1.0	ovoid	Pb-rich	30
F56	1	8	1													3.2	1.6	irreg	Pb-rich	30
F56	1	9	1													2.5	1.5	irreg	Pb-rich	30
F56	-1	10	1									x				1.8	1.7	ovoid	Pb-rich (Fe)	30
F64	1	1	1													3.6	2.0	irreg	Pb-rich (Fe)	30
F64	1	2	1									x				5.3	3.2	irreg	Pb-rich (Al/Br)	30
F64	1	3	1							x						2.0	1.5	irreg	Pb-rich with Cu	20
F64	1	4	1										x			4.0	6.0	irreg	Pb-rich with Ba Cl	43
F64	1	5	1																	

#### 4. WOODED AREAS

#### 4.1. Summary of IPA Results of Soil Litter in the Wooded Areas

[illegible]



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4.1. Summary of IPA Results of Soil Litter in the Wooded Areas (continued)

...Table Columns Continued from last page

Sample No	SEM Set No	Particle No	Tb	r	a	c	e	Ba	Al	Si	Ca	Mn	Fe	E	l	Fe	K	Ti	Cu	Zn	Cl	S	Cr	Long Diam (µm)	Perp Diam (µm)	Shape	Particle Class	Particle Class	Particle Class ID		
62B	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	3	2	2	0	irreg	Pb-rich with Sb Sn Cu	Pb-rich with Sb Sn Cu	10	
62B	1	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	7	1	0	blocky	Pb-rich with Sb Sn Cu (Al/Br S1 Fe)	Pb-rich with Sb Sn Cu (Al/Br S1 Fe)	10	
62B	1	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	1	6	blocky	Pb-rich with Sb Sn Cu (Al/Br S1 Fe)	Pb-rich with Sb Sn Cu (Al/Br S1 Fe)	10	
62B	1	4	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	5	1	1	ovoid	Pb-rich with Sb Sn Cu (Fe)	Pb-rich with Sb Sn Cu (Fe)	14	
62B	1	5	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	0	1	2	ovoid	Pb-rich with Sb Sn Cu (Al/Br S1 Fe)	Pb-rich with Sb Sn Cu (Al/Br S1 Fe)	10	
62B	1	6	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	5	1	2	irreg	Pb-rich with Sb Sn Cu (Al/Br S1 Fe)	Pb-rich with Sb Sn Cu (Al/Br S1 Fe)	11	
62B	1	7	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	3	3	2	5	irreg	Pb-rich with p Cu (Ca)	Pb-rich with p Cu (Ca)	21	
64A	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	7	2	2	irreg	Pb-rich with Sb Sn Cu	Pb-rich with Sb Sn Cu	10	
64A	1	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	9	0	7	irreg	Pb-rich with Sb Sn Cu (Al/Br S1 Fe)	Pb-rich with Sb Sn Cu (Al/Br S1 Fe)	10	
64A	1	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	5	1	7	irreg	Pb-rich with Sb Sn Cu	Pb-rich with Sb Sn Cu	10	
64A	1	4	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	4	1	0	irreg	Pb-rich with Sb p (Fe)	Pb-rich with Sb p (Fe)	15	
64A	1	5	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	4	2	1	5	irreg	Sb-rich with Pb Sn Cu (Al/Br S1 Fe)	Sb-rich with Pb Sn Cu (Al/Br S1 Fe)	3	
64A	1	6	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	1	1	5	irreg	Pb-rich with Sb Sn Cu	Pb-rich with Sb Sn Cu	14	
64A	1	7	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	8	0	4	4	irreg	Pb-rich with Sb Sn Cu (Al/Br S1 Fe)	Pb-rich with Sb Sn Cu (Al/Br S1 Fe)	14	
64A	1	8	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	7	0	4	irreg	Pb-rich with Sb Sn Cu (Al/Br S1 Fe)	Pb-rich with Sb Sn Cu (Al/Br S1 Fe)	14	
64A	1	8	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	7	1	5	irreg	Pb-rich with Sb Sn Cu (Al/Br S1 Fe)	Pb-rich with Sb Sn Cu (Al/Br S1 Fe)	10	
64A	1	8	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	9	2	7	blocky	Pb-rich with Sb Sn Cu (Al/Br S1 Fe)	Pb-rich with Sb Sn Cu (Al/Br S1 Fe)	10	
64A	1	8	4	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	6	0	7	irreg	Pb-rich with Sb Sn Cu (Al/Br S1 Fe)	Pb-rich with Sb Sn Cu (Al/Br S1 Fe)	10	
64A	1	8	5	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	0	5	irreg	Pb-rich with Sb Sn Cu (Al/Br S1 Fe)	Pb-rich with Sb Sn Cu (Al/Br S1 Fe)	10	
64A	1	8	6	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	5	0	5	irreg	Pb-rich with Sb Sn Cu (Al/Br S1 Fe)	Pb-rich with Sb Sn Cu (Al/Br S1 Fe)	10	
64A	1	8	7	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	0	irreg	Pb-rich with Sb Sn Cu (Al/Br S1 Fe)	Pb-rich with Sb Sn Cu (Al/Br S1 Fe)	10	
64A	1	8	8	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	blocky	Pb-rich with Sb Sn Cu (Al/Br S1 Fe)	Pb-rich with Sb Sn Cu (Al/Br S1 Fe)	10	
64A	1	8	9	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	4	6	3	7	irreg	Pb-rich with Sb Sn Cu (Al/Br S1 Fe)	Pb-rich with Sb Sn Cu (Al/Br S1 Fe)	10	
64A	1	9	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	7	0	9	ovoid	Pb-rich with Ba (Al/Br S1 Fe Ca)	Pb-rich with Ba (Al/Br S1 Fe Ca)	42	
64A	1	10	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	3	5	2	5	irreg	Pb-rich with Sb Sn Cu (Al/Br S1 Fe)	Pb-rich with Sb Sn Cu (Al/Br S1 Fe)	10	
64A	1	11	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	4	1	2	irreg	Pb-rich with Sb Sn Cu (Al/Br S1 Fe)	Pb-rich with Sb Sn Cu (Al/Br S1 Fe)	10	
64A	1	12	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	3	3	2	2	irreg	Pb-rich with Sb Sn P Cu (Al/Br S1 Fe)	Pb-rich with Sb Sn P Cu (Al/Br S1 Fe)	16	
64A	1	13	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	4	5	3	6	irreg	Pb-rich with Sb Sn Cu (Al/Br S1 Fe)	Pb-rich with Sb Sn Cu (Al/Br S1 Fe)	10	
64A	1	13	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	8	0	4	0	irreg	Pb-rich with Sb Sn Cu (Al/Br S1 Fe)	Pb-rich with Sb Sn Cu (Al/Br S1 Fe)	10	
64A	1	13	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	1	0	irreg	Pb-rich with Sb Sn P Cu (Al/Br S1 Fe)	Pb-rich with Sb Sn P Cu (Al/Br S1 Fe)	16	
64A	1	13	4	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	0	irreg	Pb-rich with Sb Sn (Al/Br S1 Fe)	Pb-rich with Sb Sn (Al/Br S1 Fe)	14	
76B	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	4	5	0	27	0	irreg	Mn-rich with Pb (Al/Br S1 Fe)	Mn-rich with Pb (Al/Br S1 Fe)	51
76B	1	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	4	9	3	5	irreg	Mn-rich with Pb (Al/Br S1 Fe T1)	Mn-rich with Pb (Al/Br S1 Fe T1)	51	
76B	1	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	5	0	4	0	blocky	Mn-rich with Pb (Al/Br S1 Fe T1)	Mn-rich with Pb (Al/Br S1 Fe T1)	51	
76B	1	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	9	7	5	5	irreg	Mn-rich with Pb (Al/Br S1 Fe Ca)	Mn-rich with Pb (Al/Br S1 Fe Ca)	51	
92B	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	14	5	12	5	irreg	Pb-rich with Sb Sn Cu (Al/Br S1 Fe)	Pb-rich with Sb Sn Cu (Al/Br S1 Fe)	10	
92B	1	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	4	0	2	9	blocky	Pb-rich with Sb Sn Cu (Al/Br S1 Fe)	Pb-rich with Sb Sn Cu (Al/Br S1 Fe)	10	

# 5. ROADSIDE SOIL LITTER

## 5.1. Summary of IPA Results of Roadside Soil Litter

Sample No	Set No	Particle No	Major Elements			Electron Spectroscopy			Minor Elements										Trace Elements																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																
			Pb	Sb	Sn	Al/Si	Br	Ca	Mn	Fe	K	Ti	Cu	Zn	Cl	Cr	Ni	S	P	Ba	Al/Si	Br	Ca	Mn	Fe	K	Ti	Cu	Zn	Cl	Cr	Ni	S																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																		
44B	1	1																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																	

Table Columns Continued on next page...

ENFORCEMENT CONFIDENTIAL

5.1. Summary of IPA Results of Roadside Soil Litter (continued)

...Table Columns Continued from last page

SEM		Particle										Long Perp		Particle Class		Particle Class	Particle Class																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																							
Sample No	Set No	No	No	Pb	Sb	T	P	Ca	Al	Si	Br	Fe	Mn	K	Ti	Cu	Zn	Cl	S	Diam (µm)	Shape																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																			</